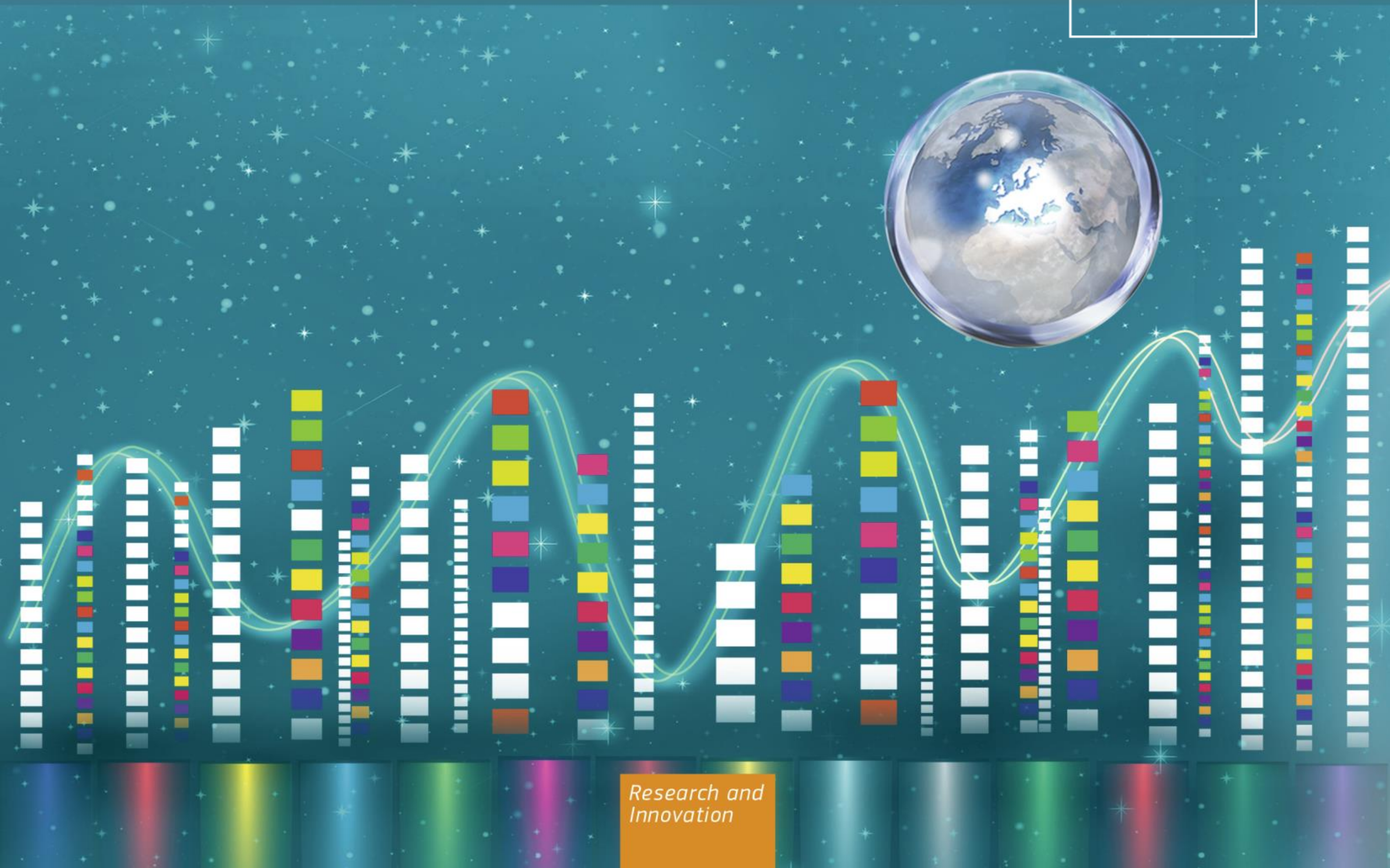
European Commission

Evaluation study
on the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness –

Focus on activities related to the Green Transition

Annexes – Phase 1 (Horizon 2020)

Independent Expert Report



Evaluation study on the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness - Focus on activities related to the Green Transition

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2023 Directorate-General for Research and Innovation EN

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ANNEX I: PROCEDURAL INFORMATION

1. Overview of the procedural information

On August 4th, 2021, the European Commission issued a request of services under the Lot 3 Studying, Assessing and Evaluating Research and Innovation Programmes and Policies (SARI) of the Multiple Framework Contract N° 2018/RTD/A2/OP/PP-07001-2018.

This request (RTD/2021/SC/023) was to conduct an evaluation study on the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness - Focus on activities related to the green transition. Proposals were submitted up to September 27th, 2021.

A consortium led by Technopolis and composed of AIT - Austrian Institute of Technology, Fraunhofer ISI, Kerlen Evaluation, Science-Metrix and ZSI was selected, and a contract to conduct this evaluation study was signed on December 12th, 2021, for a duration of 26 months.

The kick-off meeting was held on December 17th, 2021.

An inception report was submitted on February 9th, 2022, and discussed with the Steering board on February 25th, 2022.

A first interim report was submitted on June 21st, 2022, and discussed with the Steering board on June 28th, 2022.

A second interim report was submitted on October 7th, 2022, and discussed with the Steering board on October 21st, 2022.

A draft final report was submitted on December 12th, 2022, and discussed with the Steering board on December 19th, 2022.

A policy workshop was organised on January 12th, 2023.

ANNEX II: METHODOLOGY AND ANALYTICAL MODELS USED

1. Overview of the methodological approach

To conduct the evaluation, a specific methodological approach was designed during the inception phase, in agreement with the steering committee. The methodology was developed in four steps, as presented in the figure below.

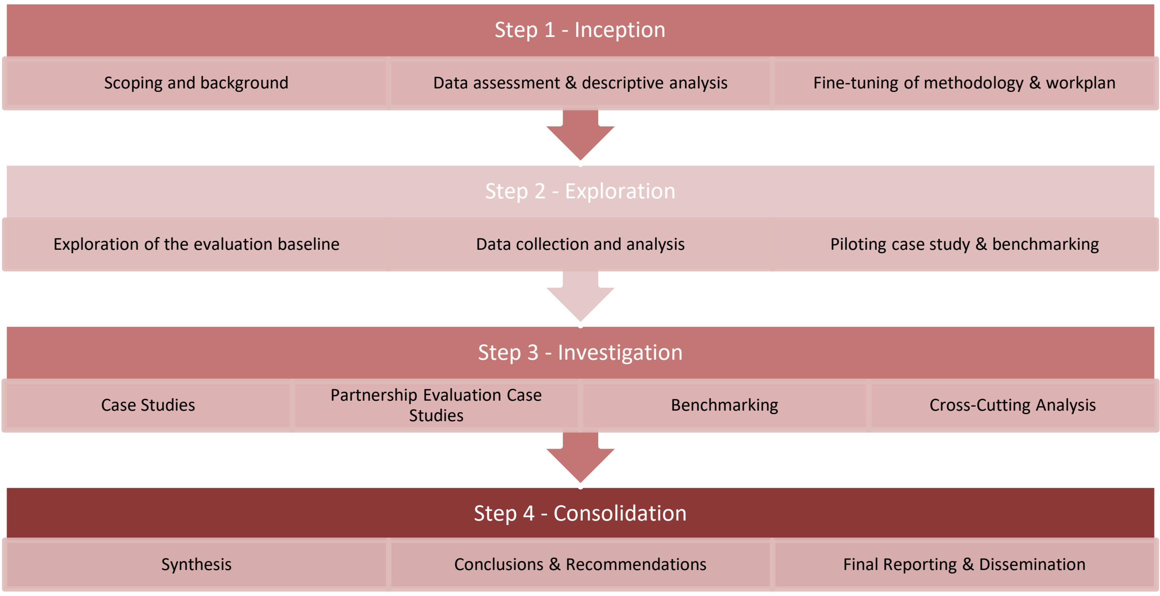

Figure 1. Overview of the four steps of the methodological approach.

The selected methodological approach mixed various data collection and data analysis tools. The different tools mobilized throughout the evaluation allowed us to collect evidence to answer the various evaluative questions considered under this evaluation. The table below provides an overview of the contribution of each tool to the different evaluative criteria.

Table 1. Correspondence between the evidence collected via specific tools and the evaluative criteria (the colour intensity reflects the importance of the tool).

Table	Relevance	Coherence	Efficiency	Effectiveness	EU added-value	Partnerships specific criteria
Desk research						
Data analysis						
Explorative interview						
International benchmarking						
Case study						

Table	Relevance	Coherence	Efficiency	Effectiveness	EU added-value	Partnerships specific criteria
Surveys						
Partnership evaluation						

As a result, several analyses were produced and provided as separate annexes:

- Topical and benchmark case studies;
- Quantitative analyses; and
- Survey results.

Results from the consultation are provided in the synopsis report.

For the partnerships under the scope of this evaluation, a specific approach was designed to cover both phases of the study. Indeed, PRIMA was the only partnership for which the evaluation was completed during Phase 1. The evaluation of all other partnerships will be completed during phase 2 of the study. In terms of partnership elements, an approach covering both phases was developed, with the collection and analysis of primary and secondary data during Phase 1, which will continue in Phase 2. An analysis of the results to date is provided in a separate annexe.

2. Challenges and mitigation measures

During this first phase, the evaluation faced several challenges. The table below presents the main challenges and the mitigation measures that were adopted.

Table 2. Main challenges faced during Phase 1 and mitigation measures.

Challenges	Mitigation measures
Delay in getting the contact details for the survey	The survey, initially planned during the second step, was eventually launched during the third step.
Low response rate to the survey	The survey, launched over the summer months, was extended by two weeks to collect sufficient responses to ensure data robustness.
Stakeholder fatigue, in a context of parallel evaluations	The EC supported the consortium to access stakeholders, and, when relevant, alternative contacts were approached.
Staff turnover	The first calls were launched years ago, and there have been changes in the organisations. The beneficiary list is large enough to collect information to ensure data robustness.
Integration of the partnerships	The full evaluation of most partnerships under the scope of this study is expected during phase 2. It is, however, expected that preliminary results are provided during phase 1. An ad hoc approach, covering both phases, was developed to provide inputs for the evaluation of Horizon 2020.
Delays in the drafting of final reports for parallel evaluations	During phase 1, the main inputs from the relevance and coherence criteria should originate from external sources, for which drafting lasted longer than expected. Primary data collection was undertaken, and the provision of the

Challenges	Mitigation measures
	external studies before the submission of the final report allowed the integration of the findings for these evaluative criteria. To the extent possible, data collection tools were aligned (e.g., survey) to allow a comparison between topical evaluations.

3. Methodological specifications for the project and call administration analyses, bibliometric analyses and technometric analyses

3.1. Core design approach for the bibliometric component

The analytical design deployed in the bibliometric component of this study resulted in the production of two sets of findings, depending on the exact analysis.

Descriptive findings, that provide bibliometric findings for selections of funded projects (in case studies), or partnerships as compared to FP7 and EU27 (non-FP). These analyses measure absolute achievements by research area or thematic area relative to selected comparators. These analyses serve to uncover where H2020 support in green transition calls stands out relative to its predecessor (FP7) as well as relative to other EU research not funded by the FP. Any outstanding performance under H2020 could relate to the programme having successfully selected projects/awardees that stand out from the reference populations and/or to the programme having exerted a positive effect on the performance of awardees. To assess the relative contribution of the latter factor in observed difference, a counterfactual analysis was then performed (see below).

Do note that, in testing (data not shown), the findings obtained for the overall, non-FP EU27 green transition research comparator were functionally equivalent to those obtained for overall, non-FP EU28 green transition research, or overall, non-FP ERA green transition research.

Counterfactual findings allow for more causal inference-making on the differential impacts of H2020 funding for supported researchers specifically. This approach was employed particularly at the SC level and the in the international benchmarking exercises. Counterfactual findings complement descriptive findings, as the differential changes measured allow Science-Metrix to better answer the question, "Did H2020-supported researchers attain the same research achievements on activities without H2020 funding?". Note that the study only reports statistically robust findings of a meaningful magnitude.

Note that, unlike the descriptive benchmarks presented above, the counterfactual analysis did not rely on any country-level filtering of publications or their authors. Any researcher that authored eCorda-indexed H2020 publications and with a (Scopus-indexed) institutional affiliation mentioned as a recipient of the specific project funding in eCorda was included in the analysis, irrespective of country of affiliation.

3.1.1. General limitation of publication-based methods

As a first general consideration, it should be kept in mind that bibliometric statistics are produced from journal publications. As such, they capture only a limited segment of research and innovation activities, practices and achievements. This is an important caveat when reviewing the findings below. For instance, a public–private partnership project could score low on the academic–private co-publication indicator but be associated with strong achievements on other dimensions of innovation activity, if actors in the project collaborated on technological and commercial development but not when writing scientific publications. This highlights the importance of using multiple lines of evidence in assessing the effects of H2020.

3.1.2. Significance of descriptive findings

Descriptive statistics have been provided at all levels of H2020. It should be kept in mind that descriptive findings are not able to tell us whether any strong performances recorded by supported researchers were induced by H2020 support itself, or whether the supported researchers would have attained these achievements otherwise, with other funding opportunities. These analyses can only show correlations between H2020 support and performance. Demonstrations of high-calibre work for any indicator may reflect H2020 support, the peer-reviewed selection process of researchers, or neither or both of these causes.

It is also important to note that the comparison to comparator publication sets here (FP7, EU27 (non-FP)) may be biased by the outsized contributions of some research areas. This will be highlighted further in the discussion on some of the relevant indicators.

More limitations about specific bibliometrics findings are introduced throughout the main text and presented in this methodological annexe.

3.1.3. Significance of counterfactual findings

In the report below, counterfactual findings have also been provided for those programmes and instruments that had enough publications for meaningful counterfactual analysis. For the counterfactual findings, only journal publications by researchers supported by H2020 funding are considered. These authors' 2014–2021 publications have been classified as either funded by H2020 or likely funded by parallel, concurrent funding from other sources (so-called "parallel" publications). Parallel publications provide a baseline against which to measure the specific incremental effect of H2020 funding on the scientific performance of supported researchers (by relevant indicator). This comparison controls for several biases, such as performance level, culture, gender, seniority and other author-level variables that might otherwise be distributed differently between the comparative groups typically used (for example when comparing H2020-supported publications against EU Member States).

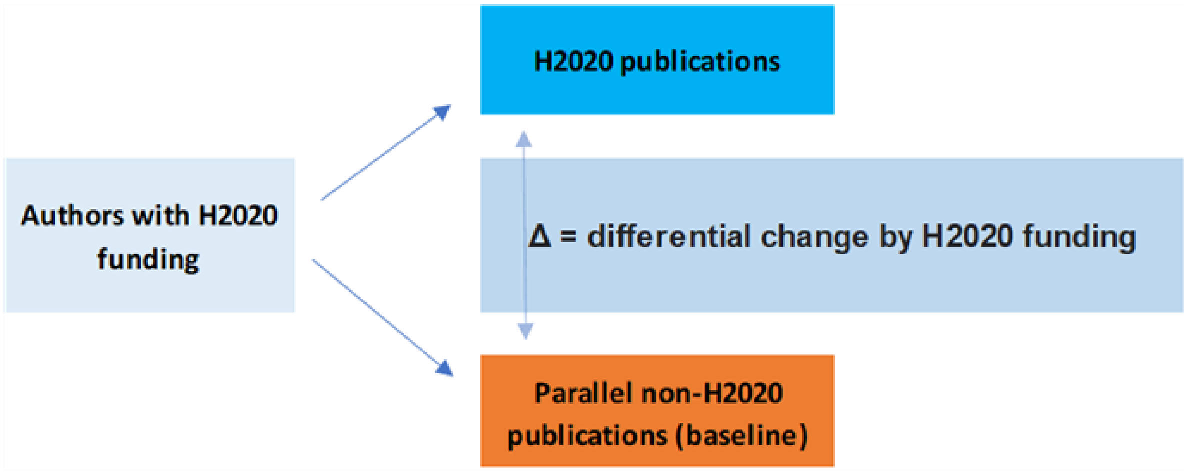

Figure 2. Visual summary of the counterfactual approach to capturing differential bibliometric outcomes of H2020-supported research.

Source: N/A

3.2. Data sources and preparation

3.2.1. eCORDA, ERA-LEARN and EIT KIC databases

The eCORDA database was provided to the evaluation group by the European Commission. This dataset includes information on proposals and projects supported by the EU's framework programmes. Some partnerships are not included in the main tables provided in this section for different reasons. For P2P partnerships (i.e. PRIMA, ERA-NET Cofund, EJP Cofund, and JPI), the tables are presented in a separate section below and were based on additional data provided by ERA-LEARN and the European Commission. This option was justified by the fact that the ERA-LEARN data appeared to be more up-to-date, compared to eCORDA (e.g. eCORDA contains 83 PRIMA projects, while the ERA-LEARN database contains 129) and because eCORDA does not include proposal data for these projects. In the case of the EIT KICs, since it is structured in the form of activities (and not projects as the remaining H2020 projects), the indicators produced followed the specific logic of reporting employed by the EIT partnerships administration.

The selection of relevant “green transition” projects was based on the H2020 topics related to the Societal Challenges (SCs) 2 to 5, as reported in the table “h20_ref_topic”. Therefore, some topics (and projects) were attributed to multiple societal challenges and not to the unique societal challenge provided in the tables “project” or “proposal”. Even though this attribution of some topics to more than 1 societal challenge appeared important to this analysis, given that many green transition projects may be relevant to multiple societal challenges, it should have, if any, a very limited impact on the final results, since only 25 topics were classified among more than 1 societal challenges (among the 2,144 topics included in any of the 4 societal challenges considered).

Projects funded under the SME instrument Phase I were excluded from the present study (a total of 1,190 SME-phase I projects, or 23.9% of the "green transition" projects selected based on the criteria described above). This filter is intended to avoid biases that could have been introduced by the inclusion of these projects, which typically involved only 1 participant with EC contribution of EUR 50,000.

3.2.2. Scopus database

For this project, Science-Metrix will use the Scopus database, produced by Elsevier. Scopus provides comprehensive coverage of the scholarly literature by indexing more than 50 million publications, published in some 180,000 peer-reviewed journals and conference proceedings since 1996. Scopus also provides the names and affiliations of all authors appearing in peer-reviewed publications, making it possible to identify publications produced by individual researchers and the institutions with which the researchers are affiliated. Scopus also indexed the funding acknowledgements of around 80% of journal publications where authors have made this information available.

The document types included in the Scopus analysis are articles, reviews, short surveys, and conference proceedings. Unless stated otherwise, the tables and figures deriving from Scopus data include all the aforementioned document types. The version of the production database proposed for this project has complete coverage of articles published up until the end of 2021. Note that publications from the years 2020 and 2021 could not be included in citation impact analyses.

3.2.3. NamSor™, Overton, PlumX, and Unpaywall databases

Science-Metrix's implementation of the Scopus database is enriched with records from the NamSor™, Overton, PlumX, and Unpaywall databases continuously, following additional preparation steps such as subfield- and year- normalisation.

3.2.4. PATSTAT database

Patents reported in eCorda as output from H2020 projects were matched to PATSTAT records to retrieve associated patent families. The version of PATSTAT used was the 2021 Spring edition.

3.3. Bibliometric indicators

3.3.1. Share of international co-publications

The share of international co-publications (or the international co-publication rate, ICR) of a researcher is his or her share of publications that include at least another author from a different country.

Given the orientation of FP programs towards increased research collaboration between countries within the EU27 and ERA zones, but also with Third countries, the ICR indicator was further refined for this project specifically to capture co-publications associated with these kinds of collaborations. That is, Science-Metrix also computed the shares of publications in a given dataset that were 1) international co-publications AND 2) were written by a first, last or corresponding author affiliated with an organization located in one of the following country aggregates:

- EU27
- EU27+UK

- ERA
- EIT RIS
- Associated Countries (incl. UK)
- Third Countries

In a hypothetical aggregate of H2020 publications, an ICR/Third Countries score of 20% would indicate that 20% of the publications in that set were 1) international co-publications between at least two countries, but possibly more and 2) an author from a Third Country was either first, last or corresponding author. The interpretation of this score would be that 20% of H2020 publications were written as international co-publications with major contributions made by Third Country authors in collaboration with the H2020-funded, presumably ERA-based authors (in principle H2020-funded publications may be written with contributions only by Third Country-based authors, although in practice the frequency of these publications is expected to be very low).

3.3.2. Publication-level average number of countries from aggregates of interest

While the ICR indicator above provides a measurement of the prevalence of a minimal definition of international co-publication (two countries or more) in a given publication set, it does not inform as to the level of diversity and variety in country collaborations found within those international co-publications. Therefore, Science-Metrix has computed the publication-level average number of countries from different country aggregates to be found in a given group of publications.

To take hypothetical examples, where H2020 programme A has on average 2.0 RIS countries listed per publication, and H2020 programme B has 1.5 RIS countries listed per publication, it can be concluded that programme A had more success in integrating RIS countries within European research and innovation networks than programme B. If programme A simultaneously had a publication-level average of EU27 countries of 1.5, then it could even be said that the programme has favoured the participation of RIS countries over and above that of EU27 countries.

Note, however, that this indicator is not restricted only to international co-publications. Therefore, a publication written by two authors from a given single RIS, non-EU-27 country will contribute a score of 1.0 to the RIS and ERA and Associated Countries categories and scores of 0 to the EU27, EU27+UK and Third Country categories.

3.3.3. Publication-level average shares of authorship from country aggregates of interest

In order to provide further refinement on the indicator of the publication-level average number of countries, it is possible to consider the share of authorships taken up by country aggregates. This indicator provides a better sense of the balance of contributions from different country aggregates at the level of single papers.

To take a hypothetical example, a publication could be co-authored by eight researchers from Germany, one from Serbia and one from Turkey. While the number of RIS countries here amounts to two out of the three unique countries listed on the paper (66.7%), the RIS share of authorship is only 20%. The two indicators are complementary and should be interpreted together.

3.3.4. Share of open-access publications

Science-Metrix has used Scopus records from Unpaywall to measure OA levels in this study. Unpaywall's database harvests content from over 50,000 publishers and repositories, containing more than 30 million entries.

OA publications in this project are those available in any OA or free-to-read modality, that is, gold, hybrid, bronze or green OA.[1]

3.3.5. Average of relative citations

The average of relative citations (ARC) is the average of the relative citation (RC) scores of all the articles published by a given entity. The ARC is normalized to 1, meaning that an ARC above 1 indicates that the entity's articles have a higher-than-average impact, an ARC below 1 means that the entity's articles have a lower-than-average impact and an ARC near 1 means that the publications have a near-average impact.

Because RC scores are known to be skewed in their distribution—with a small number of papers receiving a large share of the total citations—the ARC offers a useful snapshot of overall performance but can hide important underlying nuance. For this reason, Science-Metrix proposes to complement the ARC with the highly cited papers measure, see below.

3.3.6. Share of highly cited publications at the 10%, 5% and 1% levels

Citations are used by researchers to indicate the intellectual foundations on which their work is built. A citation count is therefore used in bibliometrics as an indication of influence within the research community. However, because citation practices vary over time and across disciplines, simply counting citations would give a skewed picture of influence. Accordingly, citation counts for individual papers are normalized by the average citation count of all papers published in the same year and in the same subfield of science.

Citation scores are highly skewed, with the majority of citations directed toward a small minority of papers. Contributions to this set of highly cited publications (HCP) are therefore often used as a proxy for research excellence. If citation behaviour was random, one would expect that every researcher would contribute equally to the population of HCP. For instance, each researcher would have 10% of their publications among the top 10% most cited worldwide. Measuring the divergence from this benchmark is used as a way to track how consistently a researcher contributes to this set of exceptionally highly cited publications.

These indicators have been subfield-, year- and document type- normalized. The world level on this indicator is 1.0.

3.3.7. Citation distribution index and citation distribution chart

The citation distribution index (CDI) is the sum of the weighted share of each decile (or each 10%) of a distribution of publications, ranked by citation count (i.e., the 1st decile includes the 10% least cited publications, the 10th decile includes the 10% most cited publications). This indicator is also normalized by year and by subfield of science. The CDI is normalized to 0 (i.e., the world average). A score above 0 indicates a level of performance above average while a score below 0 indicates the opposite.

The citation distribution chart (CDC) tool facilitates a simple but nuanced visual inspection of an entity’s research impact relative to worldwide performance (see **Figure 3. Sample of citation distribution chart**). To prepare these charts, Science-Metrix divides all publications in a given research area into 10 groups of equal size, or “deciles,”[2] based on their RC scores. The 1st decile contains the 10% of

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1 Piwowar, H. et al. (2018). The state of OA: a large-scale analysis of the prevalence and impact of Open Access articles. *PeerJ*, *6*, p. e4375. doi:10.7717/peerj.4375.

2 Two adjustments are made to ensure high-quality results, and these pertain to (a) cases where several publications are tied in their scores, and (b) cases where the total number of publications is not divisible by 10. For the first case, (a), papers tied at the margin of two deciles will be grouped together and then divided proportionately to ensure that each decile contains the right number of papers. In the case of the total number of papers not being divisible by 10, (b), papers will be fractioned to ensure that the deciles are always of exactly equal size.

publications with the lowest RC scores; the 10th decile contains the 10% of publications with the highest RC scores.

For a given research entity, it is expected that the RC scores of its publications will follow the global distribution, with an equal number of publications falling in each of the deciles. The CDC for a given entity compares that entity's scientific impact to the global level by showing how its performance compares to the world level in each of the deciles.

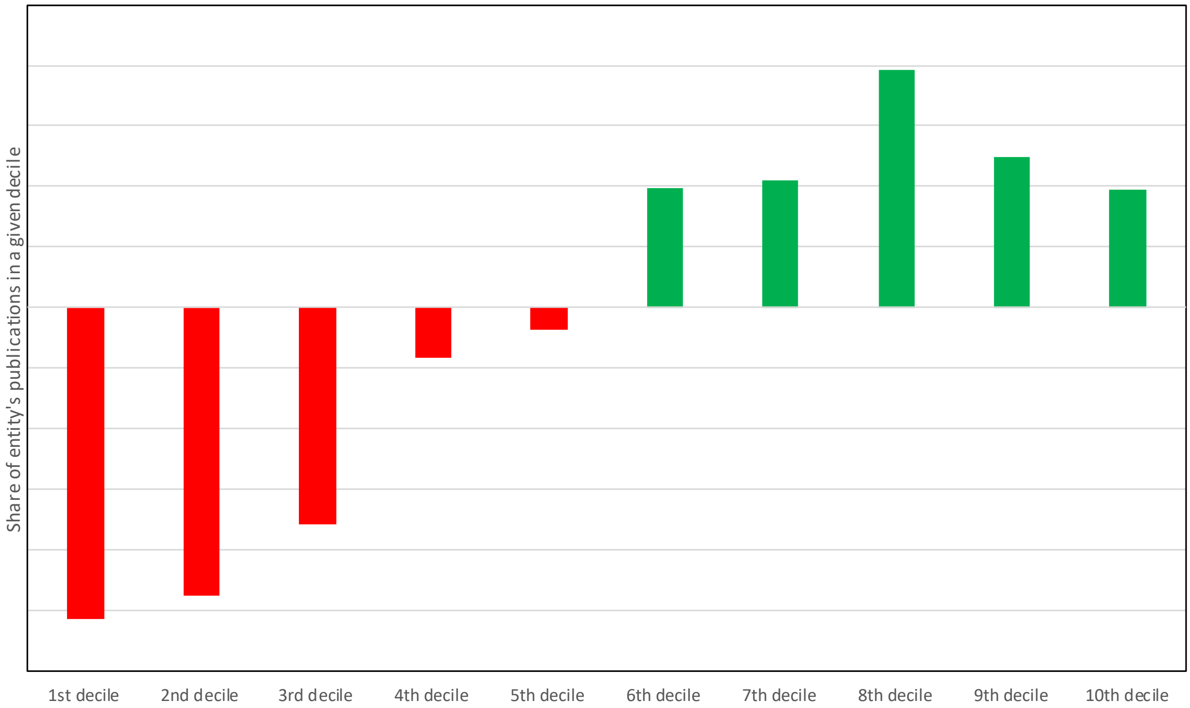

Figure 3. Sample of citation distribution chart.

Source: Prepared by Science-Metrix (Elsevier)

As shown in **Figure 3. Sample of citation distribution chart**, the CDC shows 10 colour-coded bars for a hypothetical entity; each bar represents the relative presence of this entity's papers in each corresponding decile. The world level, in contrast, is represented by the central horizontal line, with no bars, as it represents the uniform distribution of all the publications across the 10 deciles. The bar's colour shows whether the specific entity has more or fewer publications in that decile than expected (i.e., the horizontal line). A green bar denotes production exceeding expectation in that decile and a red bar denotes production below expectation in that decile.

The length of the bar shows how far above/below expectation the entity is in that decile. The longer the red bar, the fewer articles are found in that decile relative to expectation. Conversely, the longer the green bar, the more publications are found in that decile, again relative to expectation. Cases where a decile has no bar associated with it show that the entity's performance is exactly in line with the expectation based on global performance. Accordingly, a CDC with no visible bars shows that the entity in question has 10% of its papers in the 1st global decile, 10% of its papers in the 2nd global decile, and so on, which, as previously noted, corresponds to the world distribution of papers based on their RC scores.

Ideally, one would hope to have more papers than expected in the highest deciles, where the most impactful publications are found; similarly, one would hope to have fewer papers than expected in the lowest deciles, where the least impactful publications are found. Thus, strong research performance is shown by long red bars on the left of the CDC and long green bars on the right of the graph. In contrast, weaker research performance is depicted with long green bars on the left side (indicating more publications than expected in the less impactful deciles) and long red bars on the right side (indicating fewer publications than expected in the more impactful deciles). The table below presents various distributions related to best-case and worst-case scenarios.

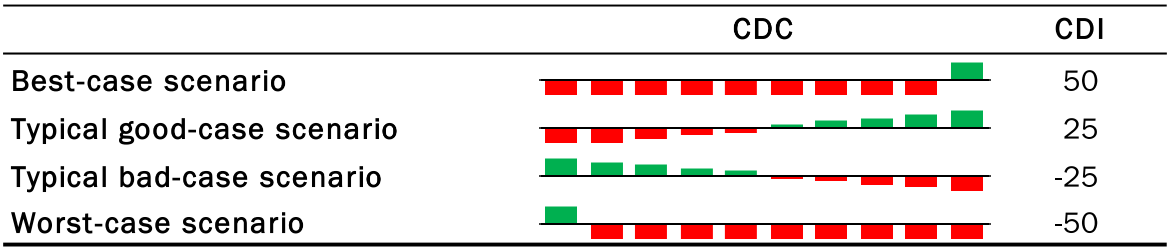

Figure 4. Various scenarios of citation distribution charts and their citation distribution index.

Source: Prepared by Science-Metrix (Elsevier)

The content of the CDC can also be summarized numerically using the citation distribution index (CDI). For each decile, the performance of a given research organization is compared to the global average, and this ratio is then multiplied by a weight corresponding to that decile, as presented below.

Table 3. Decile weighting to compute citation distribution index.

Decile	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Weight	-5	-4	-3	-2	-1	1	2	3	4	5

Source Prepared by Science-Metrix

Once a score has been produced in this fashion for each decile, the scores are summed to calculate the CDI for the research organization. Thus, having a higher-than-expected number of publications in the 1st decile (i.e., the lowest-impact decile) will reduce the CDI more than having a higher-than-expected number of publications in the 2nd decile. The CDI ranges from -50 (worst-case scenario) to 50 (best-case scenario) with 0 representing parity with the world level. Compared to mean-based normalized citation metrics, the combined use of the CDC and CDI makes it possible to provide reliable citation metrics even when dealing with entities having produced few publications (from 10 to a couple of hundred).[3]

3.3.8. Field-weighted CiteScore

The CiteScore used by Science-Metrix is calculated at the journal level as the total number of times peer-reviewed papers published in the journal in years X-1 and X-2 were cited in year X, divided by the total number of peer-reviewed papers appearing in the journal in years X-1 and X-2. As a result, using the CiteScore to evaluate individual research publications (or the entities producing them) is equating the quality of research with the quality of the journal in which they are published.

In brief, the CiteScores of papers are calculated by ascribing to them the CiteScore of the journal in which they are published, for the year in which they are published. Subsequently, to account for different citation patterns across fields and subfields of science, each paper's CiteScore is divided by the average CiteScore of the papers published in the same year in its subfield to obtain a relative CiteScore. The final indicator computation of a given entity is the average of its relative CiteScores (field-weighted CiteScores, or FWCS).

This indicator has been subfield-, year- and document type- normalized. The world level on this indicator is 1.0.

3.3.9. Interdisciplinary integration

Examining the material that is cited in a paper offers a reflection of the intellectual content that is being integrated into the underlying research. Accordingly, the integration of material drawn from across disciplinary boundaries is assessed through citation behaviours. The interdisciplinary integration (II)

3 Campbell, D., Tippett, C., Côté, G., Roberge, G., & Archambault, É. (2016). An approach for the condensed presentation of intuitive citation impact metrics which remains reliable with very few publications. In I. Rafols, J. Molas-Gallart, E. Castro-Martínez, & R. Woolley (Eds.), *Proceedings of the 21st International Conference on Science and Technology Indicators*, pp. 1229–1240. Valencia, Spain. doi:10.4995/STI2016.2016.4543.

indicator considers (a) the number of different subfields that are being cited (variety), (b) the distribution of those citations across the cited subfields (evenness; also called balance), and (c) the intellectual disparity of those subfields to one another (also called distance).

For example, a paper that draws on knowledge from four different subfields would have a higher interdisciplinarity score than a paper that draws on only three. Similarly, a paper that cites one subfield 90% of the time and the other subfields only 10% of the time would have a lower score than a paper that cites its various subfields in roughly even measure. Finally, a paper that integrates knowledge from biology and chemistry would have a lower score than a paper that integrates knowledge from biology and the performing arts, because the latter pair is more intellectually disparate than the former pair.

This indicator has been subfield-, year- and document type- normalized. The world level on this indicator is 1.0.

3.3.10. Highly interdisciplinary papers

For this study, the indicator to be computed shows what share of an entity's papers falls within the top 10% of highly interdisciplinary papers in the world (HIP; structurally similar to the HCP, see above), with each paper's interdisciplinarity score adjusted to the average of all papers worldwide published in the same subfield and same year (similar to the RC, see above).

This indicator has been subfield-, year- and document type- normalized. The world level on this indicator is 1.0.

3.3.11. Multidisciplinary integration

For this study, the index of multidisciplinary integration (MI) relies on Science-Metrix's journal-based classification of science. It reflects the diversity of the prior disciplinary backgrounds of a paper's co-authors. It is computed by adapting the metrics of Porter & Rafols to the disciplinary profile of co-authors in a paper.[4] MI was designed to increase for teams involving authors from different subfields, particularly where these subfields are not frequently connected in Scopus. It is normalized by the paper's subfield and year to avoid coverage biases.[5]

A paper co-authored by authors whose previous papers were distributed across subfields of science in a similar pattern (i.e., having similar relative frequency across subfields) would score lower than a paper bringing together authors with different backgrounds (as measured by the subfields from their prior publications), even if each of those authors, individually, had published in a less diverse set of subfields. In other words, it is the differences between the background of each co-author that increases MI and not individual authors with diverse backgrounds. Nevertheless, authors having diverse backgrounds may be more likely to increase the MI of one paper, but only if this diversity is sufficiently different from the subfields of the remaining authors. As a result of this approach, a single-author publication, no matter the diversity of its author's background, will always receive the minimum score, since the indicator is intended to capture diversity across different authors.

This indicator has been subfield-, year- and document type- normalized. The world level on this indicator is 1.0.

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4 Porter, A., & Rafols, I. (2012). Interdisciplinarity: Its bibliometric evaluation and its influence in research outputs, 20, p. 21. Retrieved from http://sites.nationalacademies.org/DBASSE/cs/groups/dbassesite/documents/webpage/dbasse_072694.pdf.

5 Campbell, D. et al. (2015). Application of an "interdisciplinarity" metric at the paper level and its use in a comparative analysis of the most publishing ERA and non-ERA universities. *20th International Conference on Science and Technology Indicators*. Retrieved from http://science-metrix.com/sites/default/files/science-metrix/publications/campbell_et_al_sti2015_short_paper_final_web.pdf.

3.3.12. Highly multidisciplinary papers

In this study, the 10% most highly multidisciplinary papers ($HMP_{10\%}$) indicator will be employed as a complementary indicator to MI. It is based on the MI indicator, reflecting the share of papers for a given entity that lies among the 10% most multidisciplinary papers in the respective subfield and year. It reduces the potential effect of outliers in MI.

This indicator has been subfield-, year- and document type- normalized. The world level on this indicator is 1.0.

3.3.13. Shares of publications with at least one woman authorship

Using the gender identification data derived from NamSor, it is possible to compute the share of publications in a given set with contributions from at least one woman author.

NamSor™, a European designer of name recognition software, was selected for this study because it offers a very high degree of accuracy and recall, in addition to its global scope, covering all languages, alphabets, countries and regions. The NamSor application programming interface (API) is also quite tolerant of typographical errors, a notably useful feature in light of the significant number of input errors in the bibliographic databases.

NamSor has implemented a rigorous protocol to assess the quality of their tool, demonstrating that it can achieve a high recall (i.e., there are very few unknowns) and accuracy (i.e., there are very few false positives) in the United States, Canada, Mexico, Russia, Japan and most European countries. Their validation procedure relies on the use of directories listing names along with their geographic location (i.e., country) and specified gendered titles (Mr. for men and Ms. for women). Using the known gender of individuals, they validate whether their algorithm attributes the correct gender.

For each combination of first name and last name, the API returns a score between -1 and 1. A score of -1 indicates a man with a certainty of 100%, whereas a score of 1 is returned for a woman, again with 100% certainty. A score of 0 denotes that gender cannot be determined at all. In fact, the API does not provide a gender for all values between -0.1 and 0.1.

3.3.14. Publication-level average of authorships held by women

Using the gender identification data derived from NamSor, it is also possible to compute the average degree to which authorship was equally shared between women and men on a given set of papers. This indicator complements the share of publications with at least one woman authorship, in that it better captures the overall distribution of authorships in a given set of publications between women and men. In an extreme scenario, it would be possible that a large proportion of publications in a given set include at least one woman author, but that women account for a minor portion of authorships for individual articles taken individually. The combination of indicators can better control for such situations.

3.3.15. Share of unique authorships held by women in the publication set

Using the gender identification data derived from NamSor, it is also possible to compute the degree to which unique authorships were equally shared between women and men when pooling all papers in a given publication set (that is irrespective of the frequency to which individual authors re-appear on multiple publications in the set).

3.3.16. Share of publications that are academic-private co-publications

Science-Metrix uses a proprietary algorithm to identify the name of major private firms within publication affiliation metadata. On this basis, it can identify shares of publications within given sets that include at least one author affiliated with a private firm.

The algorithm builds on a stock of extensive prior classification of Scopus affiliations performed by Science-Metrix throughout its 20 years of existence; on keyword-based queries derived from these prior cleaning operations; and from input from Scopus classifications of affiliations.

Note that sectoral categorization of affiliations can only be performed for organizations with a minimal number of publications in the Scopus database. It is not possible to review information for the large volume of organizations having authored or co-authored small numbers of publications in the whole Scopus database. I that this indicator does **not** make use of the private form and SME classifiers found in eCorda.

3.3.17. Percentage shares of publications associated with policy-related outcomes

The share of publications cited by policy documents captures the percentage share of an entity's papers that have been mentioned at least once in a policy document, as recorded in the Overton database. This new database captures governmental, inter-governmental (IGO such as the World Bank, WHO or IPCC) and think tank documents and parses them for citations towards the scientific literature. High shares of publications cited in this policy-relevant literature indicate that the research was particularly used in evidence syntheses and summary reports directed at policymakers. Note that many of the documents are written by governmental scientists or even academic researchers rather than civil servants or IGO staff, with a view to make scientific findings more accessible to policymakers. While the Overton database does include parliamentary records, the indicator seldom captures sustained legislative change or cannot capture instances of social change brought about by policy change – such events inherently cannot be reliably associated with specific records of scientific publications. For more in-depth discussions of policy-related uptake indicators drawn from the Overton database, please consult the relevant literature.[6]

This indicator has been subfield-, year- and document type- normalized. The world level on this indicator is 1.0.

3.3.18. Percentage shares of publications cited in patents

The proportion of articles in a given publication set to have been cited at least once by a patent (SPCP: share of publication cited by patents) can provide an approximation of the levels at which the corresponding research is "technology-relevant", or, more broadly, conducive to knowledge transfer.

It should be noted that this indicator can only be meaningfully deployed in a retrospective analysis conducted well after the periods of interest. Indeed, most patents with a reasonable probability to cite a given publication are expected to be published seven years or so after the issue of that given publication. Also, this indicator provides no signal as to whether the citing patents are themselves associated with successful, durable innovations.7 Therefore it measures uptake in technological practices, but not research transfer into successful innovation in the broadest sense.

Currently, patent citations to Scopus publications are available based on mappings of LexisNexis data from the WIPO, USPTO, EPO, JPO and IPO. Though it is to be noted that data quality for the JPO office is lower given the difference in alphabets used in a portion of the references for this office.

This indicator has been subfield-, year- and document type- normalized. The world level on this indicator is 1.0.

3.3.19. Percentage shares of publications associated with journalistic mentions or Facebook and Twitter attention

The altmetrics indicator is based on the share of papers mentioned in selected media (News, Wikipedia, Twitter, and Facebook). These indicators may indicate the degree to which research publications have piqued the intellectual curiosity of a wider audience of citizens with an interest in

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6 Pinheiro, H., Vignola-Gagné, E., & Campbell, D. (2021). A large-scale validation of the relationship between cross-disciplinary research and its uptake in policy-related documents, using the novel Overton altmetrics database. *Quantitative Science Studies*, *2*(2), pp. 616–642. doi:10.1162/qss_a_00137; Szomszor, M., & Adie, E. (2022). Overton -- A bibliometric database of policy document citations. *ArXiv*. doi:10.48550/arxiv.2201.07643.

7 van Raan, A. F. J. (2017). Patent Citations Analysis and Its Value in Research Evaluation: A Review and a New Approach to Map Technology-relevant Research Science. *Journal of Data and Information*, *2*(1). doi:10.1515/jdis-2017-0002.

scientific culture. Particularly, the news altmetrics category includes coverage in major journalistic outlets such as Smithsonian, Scientific American, the New York Times, The Conversation and other media platforms with a solid tradition of scientific reporting.

Mentions towards peer-reviewed publications can also be tracked on social media platforms including Facebook and Twitter through document identifiers such as DOI, PMID, and the URL of the article. While initial hope was that these altmetrics mentions might capture cases of knowledge transfer towards the general publication, it is now expected that most Facebook and Twitter mentions are either generated by scientists rather than a lay public; or that they capture somewhat superficial curiosity for a research finding rather than deep engagement with it.8 Nonetheless, it could be argued that the capacity of researchers to foster 'online buzz' around their findings may be indicative of their capacity to engage in public debate or vulgarization efforts. Additionally, 'online buzz' could be seen as an early step in a complex, non-linear model of knowledge transfer between 1) researchers, on the one hand, and 2) the scientifically curious public as well as a broader base of researchers than might otherwise be expected from the starting group of researchers, on the other hand.

Additionally, it appears that many observations of mentions of research outputs are generated by the originating research teams themselves, as part of legitimate online promotion and dissemination activities. should be kept in mind that members of a research team may refer to their research on their social media pages. In this case, altmetric “citations” are more representative of self-promotion activities than broad societal uptake. Disaggregating altmetric citations by source may help to distinguish between cases of self-promotion and uptake, as mentions in news outlets or on Wikipedia can more safely be assumed to amount to broad uptake, for instance.

This indicator has been subfield-, year- and document type- normalized. The world level on this indicator is 1.0.

3.4. Social network analysis indicators

Scientific research is a collective undertaking: collaboration is an important conduit for introducing new perspectives into research, highlighting assumptions, outlining new hypotheses, and sharing testing and analysis methods. The dynamics of this interconnected research ecosystem can be analyzed at the level of individual researchers and institutions, as well as at the network level, where one can find emergent properties that explain features of the ecosystem.

Network-level analyses require a delineation of actors (nodes) and types of connections between them (edges). With nodes and edges defined, numerous social network analysis tools can be applied to discover the dynamics of the system. For this specific evaluation, nodes have been defined as either the countries, organizations or sectors of participants in H20202-funded projects, and connections (edges) are joint participants in a given H2020-funded project.

3.4.1. Betweenness centrality

Betweenness centrality measures how often a given node in a network lies along the shortest paths between two other nodes that are not directly connected. For example, this indicator would highlight entities that play an important "brokering" role, acting as a connecting link between entities that do not co-publish with one another or cite one another's work directly. Nodes with a high betweenness centrality score are the bridges that connect relatively isolated islands of research communities within the overall topography. These entities play an important role in the interconnection of subgroups within the network as a whole; betweenness centrality highlights entities who may be providing an important routing service within the community, although in scientific communities this routing service is very often correlated with the intensity of productivity or participations, such as absolute volumes of publications.

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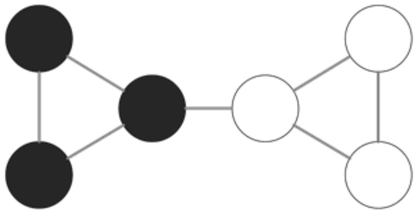
8 Pulido, C. M., Redondo-Sama, G., Sordé-Martí, T., & Flecha, R. (2018). Social impact in social media: A new method to evaluate the social impact of research. *PLOS ONE*, *13*(8), p. e0203117. doi:10.1371/journal.pone.0203117; Tahamtan, I., & Bornmann, L. (2020). Altmetrics and societal impact measurements: Match or mismatch? A literature review. *El profesional de la información*, *29*(1), p. e290102. doi:10.3145/epi.2020.ene.02.

3.4.2. Heterophily and homophily

Homophily is the tendency of entities to associate and collaborate with similar others. For example, if researchers collaborate more with other researchers from their country than with researchers from other countries then the network is homophilic in regard to the country. Homophily is thus the opposite of integration. Traditionally, homophily is calculated by comparing the average path length of nodes that share a characteristic to the average path length of all nodes in the network. In the following example, the average path length between any two nodes is 1.8, but the average path length between white nodes (or between black nodes) is 1, meaning that the network is homophilic in regard to the colour of nodes.



However, in the case of networks with disconnected components, this definition of homophily is for the most part useless because it becomes impossible to compute the average path length of disconnected nodes. Consequently, a modified version of this indicator has been developed to provide insights on homophily in such networks.

For this evaluation, heterophily and homophily have been measured for networks of organisational co-participations in individual H2020-funded projects, with organisations coded by sector of activity. Heterophilic links denote co-participation connections between organisations from different sectors, homophilic links capture co-participation connections between organisations from the same sector.

That is, a hypothetical H2020-funded project with participation from one Higher or Secondary Education Establishment and two Private for-profit entities will contribute two heterophilic connections to the overall network (two distinct PRC – HES connections), and one homophilic connection (PRC-PRC).

If the share of heterophilic connections in a network is greater than the share of homophilic connections, the network as a whole can be qualified as heterophilic, that is, fostering inter-sectoral connections. The relative value of heterophilic connections against homophilic connections is relative to the analytical design and greatly determined by the classifications of actors or organisations deployed. Homophilic connections amongst Private for-profit entities may potentially be more desirable from the standpoint of certain policies than, say, heterophilic connections between Higher or Secondary Education Establishments and Research Organisations.

ANNEX III: EVALUATION MATRIX

1. Evaluation matrix

For each evaluation criteria, we have developed a list of indicators, that help to operationalise and answer the evaluation questions raised in the terms of references of this study. The evaluation matrix provides the specific method that needs to be used in Phase 1. The evaluation matrix differentiates between three levels of analysis: 1) The Framework Programme level: evaluation questions address primarily stakeholders active throughout the FP. Questions are easily comparable across the SC/Cluster, 2) the Societal Challenge level: relates to evaluation questions referring to specific stakeholder groups which are similar at the SC. Results may be easily compared within the SC/Cluster, but not between clusters, 3)The Thematic Area: Results are most likely very specific to the specific evaluation object and may even not be easily compared within the SC/Cluster level, 4) Partnership-specific evaluation questions.

While the evaluation matrix contains all evaluation questions and indicators, it has to be noted that questions related to relevance and coherence will primarily be answered through other studies and are not the core focus of this study in Phase I.

Table 4. Evaluation matrix for Phase I.

		Level of analysis	Evaluative indicators	Methods Phase 1
RELEVANCE				
1.1.	How relevant has the Framework Programme been in this area given the stakeholders' needs and considering the scientific, technological and/or socio-economic problems and issues identified at the time of its design and over time?	SC	# Degree of fit between stakeholder needs & specific objectives # Degree of fit between STEEP challenges and specific objectives	Synthesis of results from other studies[9] Strategic & stakeholder interviews for validation
1.2.	To what extent have the supported thematic areas taken into account the latest technological, scientific and/or socio-economic developments at the national, European and international levels? What are the emerging needs in this area that the Framework Programme has not covered?	SC	# Responsiveness to STEEP trends # Number and type of emerging needs not covered by FP	Synthesis of results from other studies Strategic & stakeholder interviews for validation
1.3.	Has the Framework Programme tackled the right issues given the positioning of the European Union in this area since the programme started and over time?	SC	# Degree of fit between focus areas & conditions of EU structure in this area	Synthesis of results from other studies Strategic & stakeholder interviews for validation
1.4.	To what extent has the Framework Programme in this area addressed the needs of groups targeted for application/participation in terms of tools and thematic areas covered? Are the activities as they exist today appropriate to address the needs? What is missing?	SC	# Responsiveness of target groups (applicants/ participants) to calls in thematic areas # Satisfaction of applicants/ participants with tools and thematic areas covered ¤ Number and share of projects funded where citizens and end-users contribute to the co-creation of R&I content[10] ¤ Number and share of participating legal entities which have citizen & end-users engagement mechanisms after the end of the project	Synthesis of results from other studies Strategic & stakeholder interviews for validation
1.5.	To what extent has the Framework Programme demonstrated to be flexible to cope with changing circumstances in Europe and the world?	SC	# Number and type of changing circumstances at global and SC/Cluster level # Responsiveness to changing circumstances at global and SC/Cluster level	Synthesis of results from other studies Strategic & stakeholder interviews for validation
1.6.	To what extent have the objectives of the partnerships been, and are still relevant regarding the challenges and needs addressed in this area by the Framework Programme? How flexible have partnerships in this area proven to be in the course of their operation, in updating the	Partnerships	# Relevance of partnership objectives and activities for specific objectives of FP # Responsiveness of SRIA adaptation to changing market and/or policy needs	Partnership evaluation studies following the case study method STEEP analysis Targeted consultation Strategic & stakeholder

[9] Particularly "Evaluation study on relevance & internal coherence", "Evaluation study on the focus areas", and "Evaluation study on the implementation of cross-cutting issues"
[10] Evaluative criteria marked with ¤ are Horizon Europe Key Impact Pathway indicators

		Level of analysis	Evaluative indicators	Methods Phase 1
	Strategic Research Innovation Agendas, or equivalent strategic documents, adjusting objectives, activities and resources to changing market and/or policy needs?			interviews
1.7.	In which areas is the participation of international partners and Associated Countries the most relevant? How does this participation fit into the objectives of the Framework Programme, including the objective to reinforce Europe's relative positioning?	SC	# International collaboration per SC/Cluster and Thematic Area # Type of areas most relevant for international cooperation vs. actual participation # Added value of international cooperation for EU participants and EU	Synthesis of results from other studies[11] Strategic & stakeholder interviews for validation
COHERENCE[12]				
2.1.	How coherent has the Framework Programme been in delivering impact in the area of Green transition, in particular: - between Framework Programme parts covered by this study - with other parts of the Framework Programme not covered by this study - with other EU programmes serving similar objectives - with relevant national, regional or international initiatives	SC	# Factors that foster/hamper impact creation through synergies, complementarities	Synthesis of results from other studies[13] Strategic & stakeholder interviews for validation
2.2.	What is the positioning of the Framework Programme in this area within the overall European research and innovation landscape (incl. R&I funds at national, regional and European levels) and beyond (at the international level)?	SC	# Gaps, overlaps, synergies, complementarities between R&I funding at regional, national, European levels and beyond # Position of FP in terms of areas, value chains, TRL, type of beneficiaries	Synthesis of results from other studies[14] Strategic & stakeholder interviews for validation
2.3.	What could be done to improve the coherence of the Framework Programme interventions in this area with other initiatives to better deliver on the European Union policy objectives?	SC	# Existing mechanisms to foster synergies, complementarities and their strengths and weaknesses # Type of mechanisms that could foster synergies and complementarities	Synthesis of results from other studies[15] Strategic & stakeholder interviews for validation
2.4.	What is the level of coherence among partnerships, and between partnerships and the Framework Programme activities in this area? Are partnerships more effective in achieving synergies, compared to	Partnerships	# Type and effectiveness of partnership measures to achieve synergies among and between partnerships	Network analysis including partnership actors and FP actors in this area Case studies

[11] Particularly the evaluation studies on “Relevance & Internal coherence”, “Implementation of cross-cutting issues”, “Focus areas in H2020”, “Implementation of EIC Pilot”

[12] Coherence will be evaluated in terms of thematic areas, value chains, technological readiness levels covered, types of beneficiaries, etc. The analysis should highlight gaps, overlaps, synergies and complementarities, as well as mechanisms in place to prevent or foster those. This might include mechanisms ensuring the uptake of results between these different initiatives and in particular in the policy-making (e.g. design of the initiatives).

[13] Particularly the evaluation studies on “External coherence & synergies” and “Relevance & internal coherence”

[14] Particularly the evaluation studies on “External coherence & synergies” and “Relevance & internal coherence”

[15] Particularly the evaluation studies on “External coherence & synergies” and “Relevance & internal coherence”

		Level of analysis	Evaluative indicators	Methods Phase 1
	other modalities of the programme? (question also relevant for effectiveness)			Strategic & stakeholder interviews Synergy and good practice case studies
EFFICIENCY				
3.1.	How efficient have the implementation processes of the Framework Programme in this area been in terms of 1) administration & management, 2) project application and selection processes, 3) funding allocation, and 4) forms of implementation (e.g. partnerships, collaborative research, blending, bottom-up/top-down actions)?	FP Level, Partnerships	# Degree of satisfaction with the programme implementation process # Quality of support and services during project application and selection (Time taken to evaluate proposals, Time taken to sign grant agreement, Quality of feedback, Communication activities for attracting applicants) # Appropriateness of funding allocation / need to increase budget at programme/project level # Appropriateness of implementation (type of instruments, type of beneficiaries, composition/size of team etc.) # Appropriateness of aspects 1-5 for different types of participants (organisations) and different regions	Programme & project data analysis Participant survey Strategic & Stakeholder interviews Benchmarking Synthesis of results from "Evaluation study on proposal evaluation system"
3.2.	How did these processes cater for flexibility needs in implementation? What have been the barriers or drivers? How could they be improved or what else could be done to maximise the benefits of the Framework Programme implementation in this area? To what extent have the programme implementation processes in this area influenced the types of projects selected?	FP Level, Partnerships	# Type of needs for more flexibility # Type of existing measures that increase costs/administrative burden # Barriers and drivers for the participation of different groups # Type of measures that can contribute to increasing flexibility and decreasing costs	Participant survey Strategic & Stakeholder interviews Case studies Benchmarking Synthesis of results from "Evaluation study on proposal evaluation system"
3.3.	What can be learned in terms of implementation processes from the experience of applicants and participants? What were the key barriers and drivers towards progress they experienced at the application stage and during the implementation of the projects, and their consequences for the researchers and organisations involved?	FP Level	# External (FP conditions) and internal (Project specific) drivers and barriers for implementation of activities	Participant survey Strategic & Stakeholder interviews Benchmarking Case studies Synthesis of results from "Evaluation study on proposal evaluation system"
3.4.	To what extent are project application, management, and reporting being performed by organisations other than those performing the research and innovation activities? What are the underlying reasons and implications (e.g. in terms of costs, quality of applications, R&I	FP Level	# Share of research management services (RMS) companies active in project application, management, reporting # Costs and benefits of inclusions of RMS for beneficiaries and EC	Participant survey Strategic & Stakeholder interviews Synthesis of results from "Evaluation study on proposal evaluation system"

		Level of analysis	Evaluative indicators	Methods Phase 1
	activities) for the beneficiaries and the Commission?			
3.5.	To what extent has the Framework Programme in this area been cost-effective? How cost-effective have partnerships been?	FP Level, Partnerships	# Share of high-quality proposals funded (or not funded) by area and topic # Ability of FP & Partnerships to deliver on specific objectives with the given budgets # Cost Effectiveness in terms of ability to deliver on specific objectives against best practice interventions or other interventions with similar objectives	Participant survey Strategic & Stakeholder interviews Programme and project data analysis Benchmarking
3.6.	How proportionate were the costs of application and participation borne by different stakeholder groups, taking into account the associated benefits? Are the administrative costs borne by applicants and participants lower, higher or constant if compared with the previous Framework Programme? Please quantify them to the extent possible.	FP Level	# Increase/Decrease of costs compared with the previous FP # Appropriateness of costs compared with benefits of participation # Share of projects granted Seal of Excellence getting funding in other programmes	Participant survey Strategic & Stakeholder interviews
3.7.	How to lower the costs of application and increase benefits of participation for the applicants (i.e. cost of writing proposals) and Commission services (i.e. cost of administrating and running the programme)?	FP Level	#Measures that enable decreased costs for applicants # Measures that enable decreased costs for administrating the programme	Targeted consultation Strategic & Stakeholder interviews Benchmarking
3.8.	To what extent have the Framework Programme monitoring and evaluation systems and feedback to policy processes been efficient to ensure evidence-based policy-making in this area? Were adequate systems put in place to share lessons learned from implementation and results achieved between Framework Programme interventions in this area? To what extent does the programme communication/valorisation strategy allow identifying, capitalising upon and (possibly) transferring good practices/results?	FP Level	# Extent to which conclusions and recommendations have been considered for changes in programme design and implementation # Existence of adequate measures to share lessons learnt and results achieved # Effectiveness of the programme communication/valorisation strategy for replication and upscaling of good practices/results	Targeted consultation Strategic & Stakeholder interviews Benchmarking
	EFFECTIVENESS			
4.1.	What are the main results and (expected) outcomes and impacts of the projects supported in this area? Is the delivery of the projects' results leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?	Thematic Areas	# Scientific outcomes of the projects (e.g. publications, patents) # societal outcomes (e.g. creation of shared values, new practices within an ecosystem, contribution to policy debates or documents, strategy development) # economic outcomes (e.g. start-ups, spinoffs, increased productivity in a	Participant survey Case studies Econometric/Bibliometric analysis Patent analysis Targeted consultation Synthesis of results from studies on “counterfactual analysis”,

		Level of analysis	Evaluative indicators	Methods Phase 1
			certain field) † Publications in peer-reviewed high-impact journals in the area of the different Societal Challenges[16] † Patent applications and patents awarded in the area of the different Societal Challenges † Number of prototypes and testing activities † Number of joint public-private publications † New products, processes, and methods launched into the market ¤ R&I mission results and (expected) outcomes[17] ¤ Number of innovative products, processes or methods and (expected) number of innovations	"macroeconomic modelling"
4.2.	Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and long term? Are there any factors that are more or less effective than others, and, if so what lessons can be drawn from this?	Thematic Areas	# Drivers and Barriers to FP success in specific thematic areas # Identification of most effective measures for increasing impact	Participant survey Case studies Targeted consultation Benchmarking
4.3.	To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts? What further actions are needed to maximise the impact of the Framework Programme interventions in this area?	Thematic Areas	# Degree of effectiveness of dissemination, exploitation and communication on upscaling and replication of results # Identification of barriers and additional measures needed to replicate / upscale results	Participant survey Case studies Targeted consultation Benchmarking
4.4.	To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?	Thematic Areas	# Number and type of projects contributing to EU policy priorities and SDGs # Number and type of results achieved by projects contributing to EU policy priorities and SDGs † Percentage of the overall Energy challenge funds allocated to the following research activities: renewable energy, end-user energy efficiency, smart grids and energy	Programme & project data analysis Case studies Targeted consultation Strategic & stakeholder interviews Econometric & bibliometric analysis Patent analysis

[16] Evaluative criteria marked with † are Horizon 2020 Key Performance Indicators
[17] Evaluative criteria marked with ¤ are Horizon Europe Key Impact Pathway indicators

		Level of analysis	Evaluative indicators	Methods Phase 1
			storage activities † Percentage of EU financial contribution that is climate-related † Percentage of EU financial contribution that is sustainability-related † Percentage of EU financial contribution that is biodiversity-related ¤ Number and share of results/innovations and research outcomes aimed at addressing identified Union policy priorities and global challenges ¤ Aggregated estimated effects from the use of FP-funded results on tackling specific EU priorities and global challenges	
4.5.	To what extent has international cooperation and, more specifically, the association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme? Has international cooperation, and specifically the associations, increased the EU economic activity and jobs? (to be measured by category of Associated Countries and by part of Framework Programme in order to fully assess its impact and inform future policy choices)	SC	# Impact of international collaboration on achieving the scale and scope of environment-related objectives # Impact of international collaboration on EU economic activity and jobs by FP part and AC, Int. Coll. Country	Case studies Strategic & Stakeholder interviews Synthesis of results from (evaluation) studies on "counterfactual analysis", "macroeconomic modelling", "implementation of cross-cutting issues" Programme & project data analysis
4.6.	To what extent have the partnerships achieved their objectives and the objectives of the Framework Programme in this area?	Partnerships	# Degree of fulfilment of key objectives of partnerships (fulfilment of KPIs of Partnerships) # Contribution of partnerships to the objectives of the framework programme in this area	Partnership case studies
EU ADDED VALUE				
5.1.	What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed? Could the stakeholders have implemented their research and innovation in another way, including through other national or regional support?	Thematic Areas	# Generation of capacity to exploit economies of scale and cross-border externalities of EU intervention in this area # Policy alignment of national investments with EU priorities and creation of synergies	Participant survey Case studies Strategic & stakeholder interviews Synthesis of results from study on "Counterfactual analysis"
5.2.	What is the value resulting from partnerships in this area that is additional to the value that could result from interventions carried out at the regional or national level?	Partnerships	# Type and extent of additional value of EU-Partnerships from an EU-MS / Regional perspective (creation of policy synergies, alignment of	Case studies Targeted consultation Benchmarking

		Level of analysis	Evaluative indicators	Methods Phase 1
			national investments, coordination of national or industrial R&I agendas)	
PARTNERSHIP SPECIFIC CRITERIA				
ADDITIONALITY				
6.1.	How much private and/or public R&I contributions have been mobilised on EU priorities thanks to partnerships? What is the partnerships' budget leverage factor, in mobilising additional resources, on top of contributions from partners? How do partnerships facilitate the creation and expansion of R&I networks that bring together relevant and competent actors from across Europe, thus contributing to the realisation of the ERA?	Partnerships	(Expert Group Indicators: #Public funding generated for 1 € of EU contribution, #Private funding generated for 1 € of EU contribution, #In-kind contributions generated by 1 € of EU contribution) # Number and type of measures employed for creation and expansion of partnership R&I network # Effectiveness of measures in raising public and private funding for partnership network	Partnership evaluation studies following a case study method
DIRECTIONALITY				
6.2.	What is the progress towards the strategic vision of the European Partnerships? Do partnerships demonstrate progress in the delivery of results for the EU and its citizens, notably global challenges and competitiveness, which cannot be achieved by traditional calls alone?	Partnerships	# Impact pathways of partnerships and their progress in achieving impact # Number and share of projects/actions/results cited in (or contributing to) public policy and strategic documents (Expert Group Indicator: A robust and harmonised framework for reporting and monitoring European Partnerships in Horizon Europe June/2021) # Alignment of national/regional/sectorial policies (strategic level) (Expert Group Indicator)	n. a.
	INTERNATIONAL POSITIONING & VISIBILITY			
6.3.	To what extent are partnerships acting as global ambassadors for the European R&I system/establishing global relevance/achieving scientific and technological reputation in the international context/ serve as hubs for international cooperation, where appropriate? What is the level of international cooperation at the partnership and project level and how does this result in visibility for the European Partnership?	Partnerships	#Number and type of international collaborations of partnerships at strategic level #Number and type of international collaboration activities at project level #Number and share of projects/actions/results cited in (or contributing to) international public policy and strategic documents	n.a.
TRANSPARENCY & OPENNESS				
6.4.	How open are partnerships to new participants? Are there procedures/mechanisms in place to expand the partnership to involve new members at the partnership and project level, as	Partnerships	# Number and type of measures for attracting new partners # Effectiveness of attracting new partners (number of partners	Partnership evaluation studies following a case study method Programme & project data analysis

		Level of analysis	Evaluative indicators	Methods Phase 1
	well as gradually engage a broader set of stakeholders across Europe? Are there open and transparent processes for consulting all relevant stakeholders and constituent entities in the identification of priorities? What is the level of openness in the use of research results? To what extent are partnerships (notably with industry participation) accessible for SMEs?		widening countries, number of partners international collaboration, new type of R&I actors involved) # Number and type of consultation measures performed for defining/updating SRIAs / number and type of stakeholders reached # Number and type of measures employed for ensuring openness of research results (IPR management, openness of publications)	Strategic & stakeholder interviews
PHASING OUT PREPAREDNESS				
6.5.	What are the foreseen measures and conditions set for the orderly phasing-out of the partnership from the Framework Programme funding? Are these measures appropriate for a possible phasing-out (or renewal) of the partnership?	Partnerships	# Type of measures and conditions for phasing out partnerships # Appropriateness from stakeholders' perspective (EC, MS, Research and Innovation Organisations)	n.a.

ANNEX IV: INTERVENTION LOGICS PER SOCIETAL CHALLENGE

1. Structuring the intervention logics

The intervention logics of each Societal Challenge of Horizon 2020 take into account the **general objectives** of Horizon 2020 and the **specific objectives** for each Societal Challenge. Then, they are structured along distinct types of inputs, outputs, outcomes, and impacts that have been identified via desk research of strategic programming documents and scoping interviews.

The identified inputs comprise: 1) projects funded under the Framework of Horizon 2020 by main type of project, 2) R&I Actions (Research and Innovation Actions, Innovation Actions, Coordination and Support Actions, the SME Instrument, 3) Innovation Procurement, 4) and the Public-Private Partnerships (Joint Technology Initiatives, cPPPs) and Public-Public Partnerships (Art. 185 Partnerships, ERA-NET CoFunds, Joint Programming Initiatives) under Horizon 2020 and the EIT-Knowledge and Innovation Communities.

The identified **outputs** comprise: 1) **technological outputs:** New technologies, components, systems, innovative processes, improved cost-resource efficiency of technologies etc.; 2) **scientific outputs:** scientific publications, project reports, research tools and methods, joint databases, conferences/workshop presentations etc., trained researchers; 3) **Networks:** research and innovation networks and community building across sectors and disciplines; 4) **Close to market outputs:** Intellectual property rights, innovative business models, new solutions, start-ups, spin-offs, 5) **Policy outputs:** New or improved standards, reference models, inputs to policy-making processes and regulations.

The identified outcomes comprise:

- **Coordination & Collaboration:** this outcome relates to the increasing importance of collaboration between different stakeholders (from researchers to relevant public authorities responsible for policy making, the business enterprise sector as a major provider of solutions, and representatives from civil society), different research disciplines and geographical extent.

- **Knowledge Creation & Capacity Building:** this outcome relates on the one hand to the need to develop new knowledge and methods as well as frameworks for the systematization of data and enabling decision support, while on the other hand, there is a need for dedicated capacity building & training activities among different target stakeholder groups for preparing the capacity to uptake and circulate solutions.

- **Technology & Innovation:** this outcome relates to the importance of providing systemic technological solutions and integrated sectoral services for the green transition. It concerns the deployment of a portfolio of solutions as part of a new system or their deployment and integration into an existing system.

- **Market & business:** this outcome relates to improving the marketability and feasibility of solutions. It emphasizes the requirement to follow a need and demand-driven approach for the area under consideration. Pilot and demonstration activities should enable testing solutions in practice and facilitate replication, upscaling, and new business models.

- **Policies and Standards:** this outcome relates to the need to facilitate better policy planning and better institutional governance arrangements (e.g., multi-level, cross-sectoral, cross-system). Furthermore, new technical standards and standard-setting measures as well as adapted regulations are needed to drive a green transition.

The outcomes of the activities contribute to certain types of impacts. For structuring the impacts of the intervention logics, four impact domains have been identified:

- **Economic Domain:** relates to impacts on the economic environment such as overall economic growth and jobs, international competitiveness, security of supply, and creation of new markets.

- **Environmental Domain:** relates to ecological effects such as overall reduction of GHG emissions, transition to a sustainable economy, and reduction of waste and pollution.

- **Social Domain:** relates to changes in consumer behaviour (consumption patterns), and affordability of sustainable solutions.

- **Value Domain:** relates to changes in social acceptance of common targets, norms and values conducive to a green transition among European policy actors, producers and consumers.

2. Analysis of transition processes induced by the intervention

To analyse, to which extent Horizon 2020 has induced processes for a green transition, the evaluation uses the concept of the Multi-Level Perspective (MLP) (Rip and Kemp, 1998; Geels, 2002; Smith et al., 2010), and the concept of transformative outcomes (Ghosh et al. 2021).

The MLP argues that transitions come about through dynamic processes within and between three analytical levels as described in Köhler et al. (2019): 1) niches, which are protected spaces and the locus for radical innovations; 2) socio-technical regimes, which represent the institutional structuring of existing systems leading to path dependence and incremental change; and 3) exogenous socio-technical landscape developments. According to Brodnik et al. (2021) the three levels are characterized as follows:

- At the niche level, new ideas and ways of working emerge. Often starting at small and local levels, these can grow into alternative arrangements that combine a system's social and technical elements. Radical innovations are assumed to emerge in niches, where new entrants (pioneers, entrepreneurs) nurture the development of alternatives (Rip and Kemp 1998). These niche innovations may break through more widely if landscape developments put pressure on the regime that leads to cracks, tensions and windows of opportunity.

- The regime represents a highly stable and entrenched set of rules, technologies and social elements that guide actors within a system and create pathways along which incremental change can take place.

- Niches and regimes are embedded in a broader social and technical landscape. This is made up of the physical world, shared cultural beliefs, political ideologies and large-scale trends such as global warming. Together, they create a ‘gradient of force’, which makes some actions easier than others.

Departing from the MLP Ghosh et al. (2021) identify three general spatially bounded macro mechanisms that actors can have control over to manage and steer transitions: (1) building or nurturing niches; (2) expanding and mainstreaming niches, and (3) opening up and unlocking regimes. These so-called "transformative outcomes", are processes for which actors (e.g., programme owners/managers and project leaders) can try to induce and steer for managing transition processes. For each of the three macro-processes, Ghosh et al. identify the following four specific processes, that can be important leverage points for transition processes:

Building and Nurturing Niches

- Shielding: protecting new and more sustainable practices from external influences and helping them grow.

- Learning: providing regular opportunities for discussing experiences, obstacles and needs related to a new practice as well as challenging related values and assumptions that people might have.

- Networking: protecting and progressing new practices by gaining the interest of more people and creating connections between them.

- Navigating expectations: navigating and converging expectations of different actors the legitimacy of new practices is developed and their potential explored.

Expanding and mainstreaming niches

- Upscaling: conducting deliberate action to get more users involved in new and more sustainable practices.
- Replicating: transferring the new and more sustainable practices to another location Enabling cooperation.
- Circulating: exchange of knowledge, ideas and resources between multiple related alternative practices.
- Institutionalising: turning new and more sustainable practices into more permanent and more widely available ones.

Opening up and unlocking regimes

- De-aligning and destabilising regimes: disrupting and weakening dominant practices. This can be done by changing one of the dominant dimensions for example through the introduction of new policies.
- Unlearning and deep learning of regime actors: dominant actors question their assumptions and change their view on the potential of new and more sustainable practices and the ability of the dominant practice to respond to threats and opportunities, such as climate change and digitalisation.
- Strengthening regime-niche interactions: Frequency and quality of interactions between empowered actors from the niche and the regime on a non-competitive basis.
- Changing perceptions of landscape pressures: dominant actors to reach the point of view that immediate action is warranted, and new emerging more sustainable narratives need to be promoted.

For contributing to transition processes, research and innovation (R&I) can play a considerable role in providing the desired directionality for R&I efforts, the foundational technological requirements, and the technological and social innovations for shaping the transformation to a green European society, paving the way for the required behavioural change through integration of all stakeholders including civil society. The Multi-Level-Perspective and the concept of Transformative Outcomes provide means to better grasp, whether and to which extent Horizon 2020-funded research and innovation activities have induced transformative processes, contributing to a green transition through its directionality of funding aiming at the creation of new fields of innovation conducive to a green transition, the bundling of all necessary actors to introduce transformative change, and the power to contribute to a faster circulation and transfer of knowledge into practice.

Against this background, the specific intervention logics for each Societal Challenge Area are presented in the next sections.

3. Societal Challenge 2 “Food, Agriculture, Water and Bioeconomy”

SC 2 addresses a broad range of challenges that are associated with the transition from a fossil-based economy towards the use of biological and renewable resources and therefore the need for sustainable primary production and processing systems. This includes the mitigation of key global challenges including the adaptation to and mitigating of climate change; ensuring food security; safeguarding the natural resource base, promoting alternatives to fossil-based economies and sustainably using marine resources while protecting the oceans.

Against this background, Horizon 2020 defines the following four major focus areas with specific goals and objectives:

- **Sustainable Food Security**: i.e., Not only to meet the growing demand for food worldwide but also to provide healthy food and enable healthy consumption while reducing negative environmental and societal impacts.

- **Blue Growth:** Unlocking the potentials of aquatic living resources while protecting ocean and water environments.

- **Rural Renaissance:** Enabling opportunities for sustainable growth in rural areas leading to more and better jobs, a better environment, and better social and territorial cohesion.

- **Bioeconomy:** Strengthening the European bioeconomy.

While these objectives are multiple and broad, the emphasis in the first two Work Programmes was on socio-economic objectives, to strengthen the competitiveness and foster growth of primary and process industries on land (including rural areas) and sea. An important emphasis was to break up sectoral isolation and to foster cross-sectoral activities on land (e.g., different application sectors using biomass, innovation along food value chains) and sea (transport, fisheries, tourism, aquaculture, wind farms).

A considerable development took place during the H2020 implementation in SC 2 with a clear shift towards environmental objectives and impact. In line with the relevant strategies developed in parallel, such as the Farm-to-Fork strategy[18] and the Green Deal.[19]The last Work Programme reflects the growing awareness that the existing approaches to foster the bioeconomy, as well as agriculture, food and marine, cannot be considered sustainable per se. Therefore, the issue of sustainability receives more attention and raises the question of how to implement those approaches/foster those paths that have a high sustainability potential (e.g., industrial uses based on waste on residues instead of sugar for industrial products). Here, not only (but of course as well) the potential to reduce CO2 is of high relevance, but e.g., the simultaneous land intensification and related negative sustainability effects, as well as social (food security, health, rural living) issues, have to be addressed.

The figure below shows how Horizon 2020's work programmes have progressed through their respective calls for SC 2 during 2014-2020.

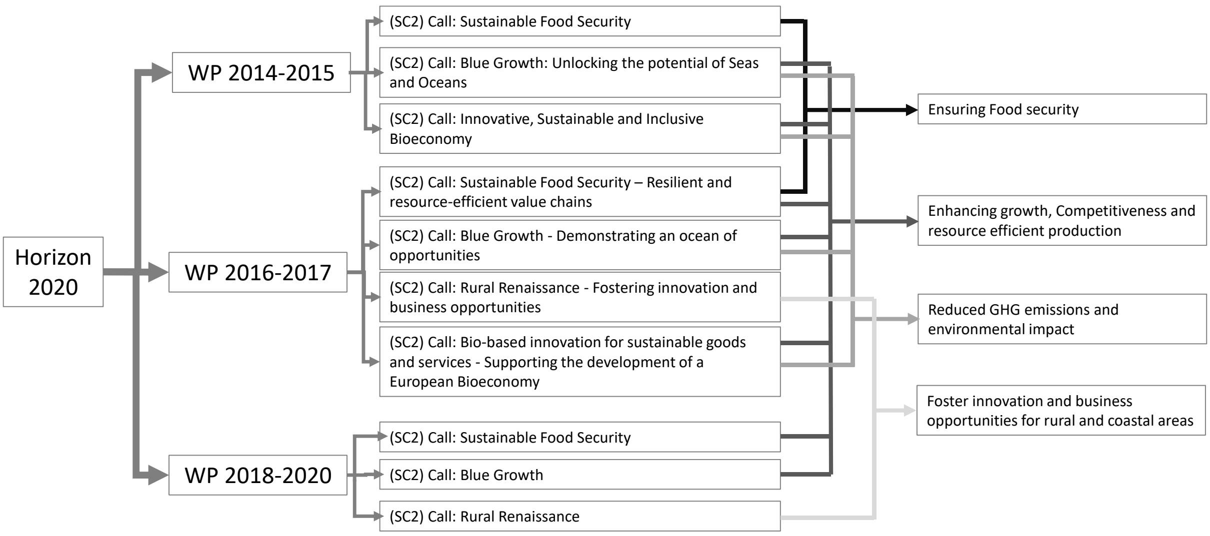


Figure 5. Horizon 2020 SC 2 Calls and their WP focus/ priority areas.

Source: Own illustration.

The whole type of objectives and related results, outcomes and impacts are reflected in the Intervention Logic diagram. As far as possible, heterogeneity in thematic and geographical have been taken into account, since:

[18] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0381
[19] These strategies complement other relevant strategies for primary production with agriculture, forestry and marine/maritime, such as the Common Fisheries Policy (CFP), the Common Agriculture Policy (CAP) and the EU Forest Strategy and further develop former strategies such as the Bieoconomy Strategy first launched in 2012.

- the geographical context differs greatly in the EU, with very different importance and characteristics of the different types of primary production (e.g., coastal areas, countries with large forestry, etc.) and related industries; and

- various foci have emerged at different times and are in different stages of maturity. For example, the Blue Growth focus area mainly addresses new approaches in early TRL stages so rather key outputs than long-term impact e.g., related to SDG 14 can be expected. On the other hand, for bio-based products, the Flagship projects aim to de-bottleneck upscaling, and it can be expected that an increasing number of products is getting very close to market entry.

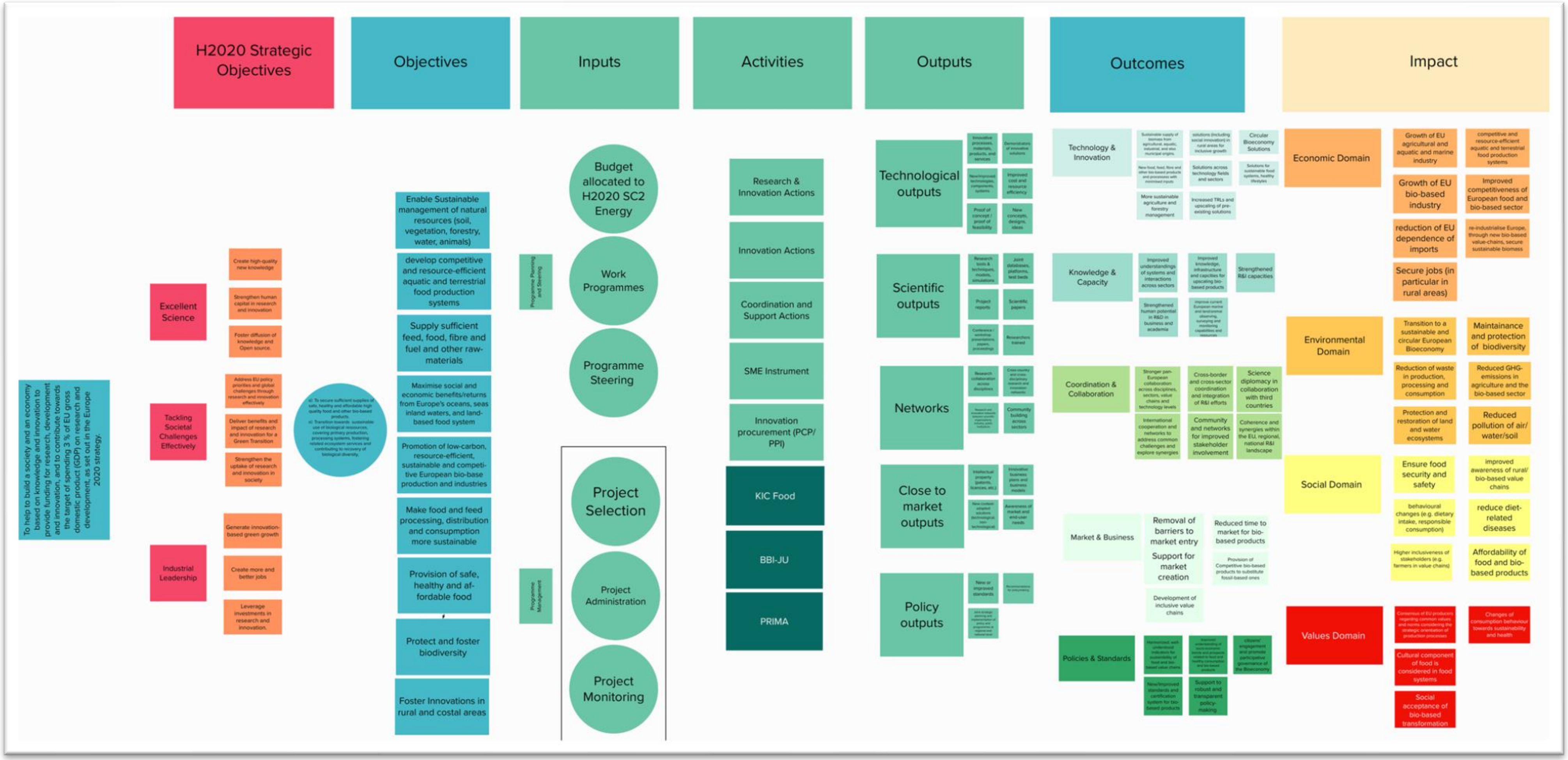


Figure 6. SC 2 – Food, Agriculture, Water and Bioeconomy Intervention Logic.

Source: Own illustration

3.1. Objectives for SC 2 – Food, Agriculture, Water and Bioeconomy

The overarching objectives of SC 2 are to:

- Secure sufficient supplies of safe, healthy and affordable high-quality food and other bio-based products, and
- Enable the transition towards sustainable use of biological resources, covering primary production, and processing systems, fostering related ecosystem services and contributing to the recovery of biological diversity.

Based upon these objectives, specific objectives for SC 2 Food, Agriculture, Water and Bioeconomy are:

- Enable sustainable management of natural resources
- Develop competitive and resource-efficient aquatic and terrestrial food production systems
- Supply sufficient food, feed, biomass and other raw materials
- Maximise social and economic benefits/ returns from Europe's oceans, seas, inland waters and land-based food systems
- Promote low-carbon, resource-efficient, sustainable and competitive European bio-based production and industries
- Make food and feed processing, distribution and consumption more sustainable
- Provision of safe, healthy and affordable food
- Protect and foster biodiversity
- Foster Innovations in rural and coastal areas

The final work programme of Horizon 202020 added the goals of "Making the transition towards a circular bioeconomy" and "Fostering functional ecosystems, sustainable food systems, healthy lifestyles". Restoration and regeneration of ecosystems beyond the mere maintenance of the status quo have been taken into stronger consideration and stakeholder participation and behavioural change have been taken into focus. In addition, social goals gained significant relevance, which is for example reflected in the activities geared towards the creation of inclusive value chains along primary production, aiming to enable farmers to establish value chains that provide them with additional income opportunities and less dependence on the (large) food processing companies.

3.2. Inputs for SC 2 – Food, Agriculture, Water and Bioeconomy

To achieve these goals, Horizon 2020 made use of all its instruments including European Partnerships for Research and Innovation. A total budget of EUR 3.54 billion was allocated by the EC to SC 2 since 2014, resulting in a total of 687 projects, including one Art. 187 partnership BBI), which received EUR 822 million of EC contribution and funded 142 projects.

The European Partnership BBI (Art. 187) has been set up at the beginning of Horizon 2020. During its implementation Art. 185 PRIMA (currently 53 EU-funded projects with a contribution of EUR 110 million; in total EU contribution of EUR 220 million is planned) and the EIT KIC Food have been set up. Those instruments present a greater portfolio than the one that has been deployed in earlier framework programmes for this area. E.g., the BBI JU addresses with the Demonstration and Flagship projects a bottleneck of very high relevance for the bio-based industry, namely the issue of scaling-up, which is not only resource intensive but specifically challenging because of different types of feedstocks, different reactions of substrates in higher scale, etc.

Moreover, international cooperation, e.g., partnerships with Africa, has become very relevant in the Horizon 2020 Work Programmes of Societal Challenge 2. These activities may lead to expected outputs such as increased international cooperation and a larger geographical scope of expected outcomes and impacts.

3.3. Expected Outputs for SC 2 – Food, Agriculture, Water and Bioeconomy

The direct outputs of these projects cover a wide range of subjects which can be grouped under five headings. Due to the large number of calls and projects in SC 2, these are described in rather generic terms.

- **Technological Outputs**: The project calls within SC 2 have been structured to produce a broad range of technology-based outputs, such as innovative processes/ products/ services or new technologies/ components/ systems or demonstrators of innovative solutions. Moreover, upscaling to pilot and in some cases demonstration plants (in BBI) has been achieved. The aimed technology outputs cover a wide range of areas, e.g., biological and life sciences, offshore solutions (including observatory systems), specific ICT solutions (e.g., for agriculture), and different kinds of conversion technologies for biomass (including waste and residues).

- **Scientific outputs**: Projects' scientific outputs include project reports, scientific papers and presentations in conferences and workshops. They also include enhanced research tools and techniques, models and simulations, new common methodologies as well as joint databases, platforms and test beds. Project outputs also include information material for user communities, while research results and data have been provided in open access and researchers have been trained.

- **Networks**: The establishment of new and enhanced networks and platforms for R&I have been included as part of an effort to develop improved collaboration across different disciplines, priorities and countries. In particular, cross-sectoral community building is central for SC 2 and cross-sectoral networks and activities have been fostered on land (e.g., across different application sectors using biomass) and sea (across transport, fisheries, tourism, aquaculture, and wind farms).

- **Close to market outputs:** Outputs with a higher technology or market readiness include intellectual property (patents, licences, etc.), innovative business plans and business models as well as new context-adapted technological and non-technological solutions. These outputs also include better awareness of market and end-user needs.

- **Policy outputs:** Recommendations for policy-making and contributions to new or improved standards are important policy-related outputs provided. On the level of public sector collaborations, joint strategic planning and implementation of policy and programmes at regional and national levels as well as joint calls launched between national authorities are other policy outputs expected within the area.

3.4. Expected outcomes for SC 2 – Food, Agriculture, Water and Bioeconomy

Outcomes are expected in five complementing areas. These results are more specific to the transport and mobility societal challenge.

- **Technology and innovation**: Expected outcomes comprise a sustainable supply of biomass from agricultural, aquatic, industrial, and also municipal origins. Therefore, sustainable management of, soil, forestry water and biodiversity as providers of terrestrial and aquatic ecosystem services have to be achieved. The expected outcomes also include the use of biological knowledge as well as the development of digital solutions that foster resource efficiency and the use of secondary resources or residues. Regarding the use of bioresources from land and seas scale-up of technologies, products and services are established. The solutions will not only cover new technologies, but also include social innovation and behavioural change (e.g., towards healthier and more sustainable lifestyles). In the later stage of H2020, circular bioeconomy solutions are envisaged, which comprise resource-efficient production and distribution systems, value chains based on new and more efficient use of wastes, residues and by-products, as well as innovative business models.

- **Knowledge and capacity**: Projects funded under SC 2 are expected to allow access to knowledge and contribute to a better understanding of agriculture, food, aquatic and bio-based systems and interactions across sectors as well as the socio-economic contexts of the transition to the bioeconomy including societal needs, consumer behaviour and uptake of sustainable solutions. Regarding R&D capacities and knowledge, projects are expected to contribute data and knowledge for sustainable preserving, production and use of bioresources solutions as well as world-class research facilities and to improve the knowledge and skills of the workforce related to the bioeconomy, food, agricultural and maritime area. Particular advances are expected in the less mature fields of bio-based products or exploitation of marine resources to improve knowledge, infrastructure and capacities for upscaling.

- **Coordination and collaboration:** Expected outcomes are a stronger pan-European collaboration across disciplines, sectors, value chains and technology levels in general and better cross-border and cross-sector coordination and integration of research and innovation efforts in particular, leading to increased coherence and synergies within the EU, regional, national R&I landscape. Moreover, at least for some thematic fields (agriculture, field), international cooperation beyond the EU is expected to be strengthened. These networks will contribute to scientific excellence and coordinated efforts to provide new solutions, but also to better science diplomacy with less developed countries. Additionally, a focus is also on increased industrial participation in R&I efforts to enable European production capabilities and supply chains, as well as a stronger involvement of civil society and consumers to enable active participation in the transition towards the bioeconomy.

- **Market and business:** SC 2 aims to keep the agricultural industry competitive while transitioning towards more sustainable practices. Moreover, for bio-based products (including marines' resources) as well as food new competitive value chains compared to existing solutions will be established. Therefore, results are expected to manifest in a more competitive industry, strengthened production capabilities and supply chains in Europe while limiting sustainable burden and improving inclusiveness. Projects are expected to reduce time to market for innovative technologies and solutions and increase market uptake for innovative, resource-efficient solutions through, inter alia, the effective removal of non-technological barriers.

- **Policy and standards:** An enhanced alignment and synergy of agricultural, food and bioeconomy policy is expected as a result of SC 2 as well as an improved understanding of socio-economic trends and prospects related to food and healthy consumption. Moreover, the use of new data on terrestrial and aquatic ecosystems (e.g., Sea Observation data) will lead to a better understanding of climate change and support evidence-based policymaking. Furthermore, more innovation conducive regulatory frameworks, new and/or improved standards for technologies, and services as well as the better harmonization of sustainability assessment of food and bio-based value chains and certification are expected. Also, higher levels of citizen engagement and participative governance in the Bioeconomy are realized.

3.5. Expected impacts for SC 2 – Food, Agriculture, Water and Bioeconomy

Impacts are expected to be achieved in four areas – the economic, environmental, social and values domains.

- **Environmental domain**: A contribution towards a reduction in the production and use of bio-resources and of waste generation, pollution and GHG emissions are expected as a result of SC 2 as well as maintenance and protection of biodiversity and ecosystems. In addition, land and water ecosystems are also restored.

- **Economic domain:** In the economic domain, the EU is expected to take technological leadership and leadership in global markets for opportunities in the use of bio-resources, with the diffusion of innovation generating jobs, growth and investment in the industry. Moreover, competitiveness and jobs in primary production and food systems, which are often located in rural areas, are secured. Such a position will also reduce EU dependence on imports, e.g., of fossil resources or fish.

- **Social domain**: Ensuring food security and safety in Europe is expected within the social domain with affordable prices for food and bio-based products. In addition, there will be higher inclusiveness of stakeholders (e.g., farmers) in bio-based value chains. On the side of consumption, behavioural changes (e.g., dietary intake, responsible consumption) towards healthier and more sustainable life.

- **Values domain**: Impacts in the values domain is expected to be a publicly accepted and supported transition of the food system towards a bioeconomy, where consumption behaviours are changed towards sustainability and health. Moreover, the cultural component of food systems is considered, as well as more consensus regarding common values and norms considering the strategic orientation of production processes (e.g., use or abundance of certain technologies) is achieved.

4. Societal Challenge 3 “Secure, clean and efficient energy”

One of the major challenges Europe will face in the coming decades is to transform its energy system, allowing for secure, affordable and efficient energy. The European Union and its Member States have committed themselves to the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) and play an active role to maximize progress towards the SDGs. In 2020, the EU submitted its long-term strategy for low greenhouse gas emission development to the United Nations Framework Convention on Climate Change (UNFCCC), in line with the Paris Agreement. SDG 7 ("Ensure access to affordable, reliable, sustainable and modern energy for all") calls for ensuring universal access to modern energy services, improving energy efficiency and increasing the share of renewable energy, and is the main reference strategy for energy transition-related activities within the EU.

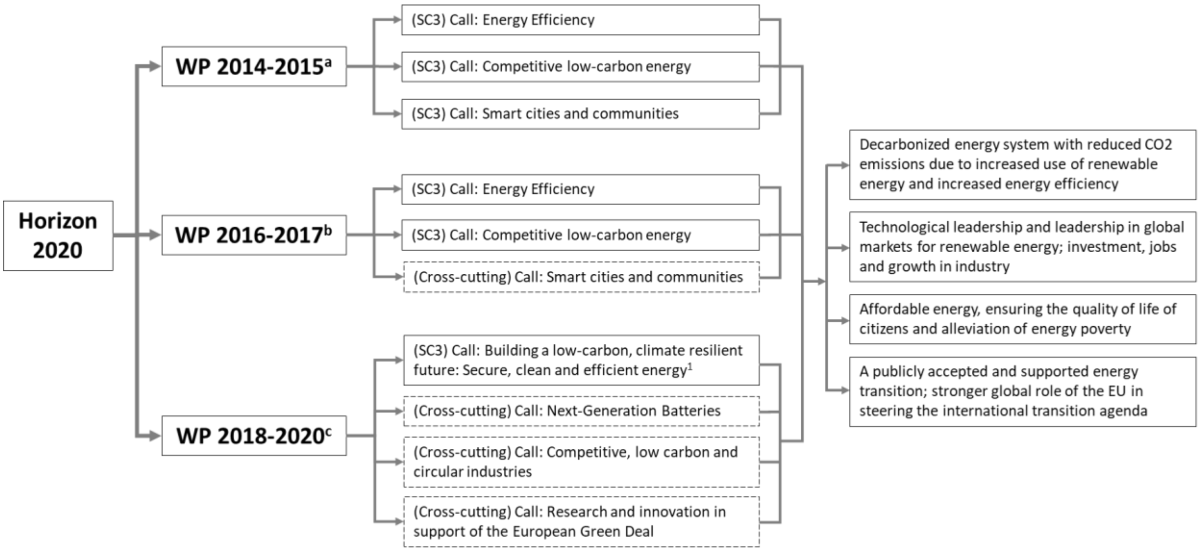
With the European Green Deal, the EC adopted a set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030. The Green Deal focuses on 3 key principles for the clean energy transition, which will help reduce greenhouse gas emissions and enhance the quality of life of citizens:

- ensuring a secure and affordable EU energy supply
- developing a fully integrated, interconnected and digitalized EU energy market
- prioritizing energy efficiency, improving the energy performance of our buildings and developing a power sector based largely on renewable sources

Societal Challenge 3 was established to respond to the need to reduce fossil fuel dependency in the face of increasingly scarce resources, increasing energy needs, and climate change. To address the needs, the specific objective for the Energy Challenge established in the legal base of H2020 was to “make the transition to a reliable, affordable, publicly accepted, sustainable and competitive energy system”.

Since the conception of the Societal Challenge, “Secure, clean and efficient energy” (SC 3), several international and European strategies and initiatives have emerged that have changed the overarching reference framework for SC 3, particularly the Paris Agreement and most recently the European Green Deal. According to interviews, the European Green Deal marked another major milestone in the evolution of European and international climate and energy policy progressing from, inter alia, the Rio Conference, the Kyoto Protocol, and COP21. The European Green Deal introduced more ambitious targets for the energy transition. In that sense, the European Green Deal increased the level of ambitions for the energy sector, while simultaneously marking a radical shift within European policymaking as its objectives were enshrined into the European Climate Law.

SC 3 addressed the European Green Deal through a substantial contribution to the cross-cutting activities (Work Programme 2018-2020). Hereby, mainly Area 2, "Clean, affordable and secure energy", Area 3, "Industry for a clean and circular economy", and Area 4, "Energy and resource-efficient buildings" are the most relevant areas of call topics.



[a] **WP 2014-2015** includes SC3 contribution to the SME instrument and the EIC Fast track to innovation for energy
[b] **WP 2016-2017** includes SC3 contribution to the SME instrument, the Fast-track-to-Innovation pilot, Smart and Sustainable Cities, and Blue Growth - Demonstrating an Ocean of Opportunities
[c] **WP 2018-2020** includes SC3 contribution to contributes to the ICT Focus Area "Digitising and transforming European industry and services," and to the SME instrument andthe EIC Fast track to innovation for energy
[1] Call includes, inter alia, Energy efficiency, Buildings in energy transition, Global leadership in renewables, Smart cities and communities

Figure 7. Horizon 2020 SC 3 Calls, their WP focus/ priority areas and impact domains.

Source: Own illustration

The figure above shows how Horizon 2020’s work programmes have progressed through their respective calls for SC 3 during 2014-2020. The objectives have remained constant over the years. An indication is also provided where SC 3 has contributed to other societal challenges or focus areas within Horizon 2020.

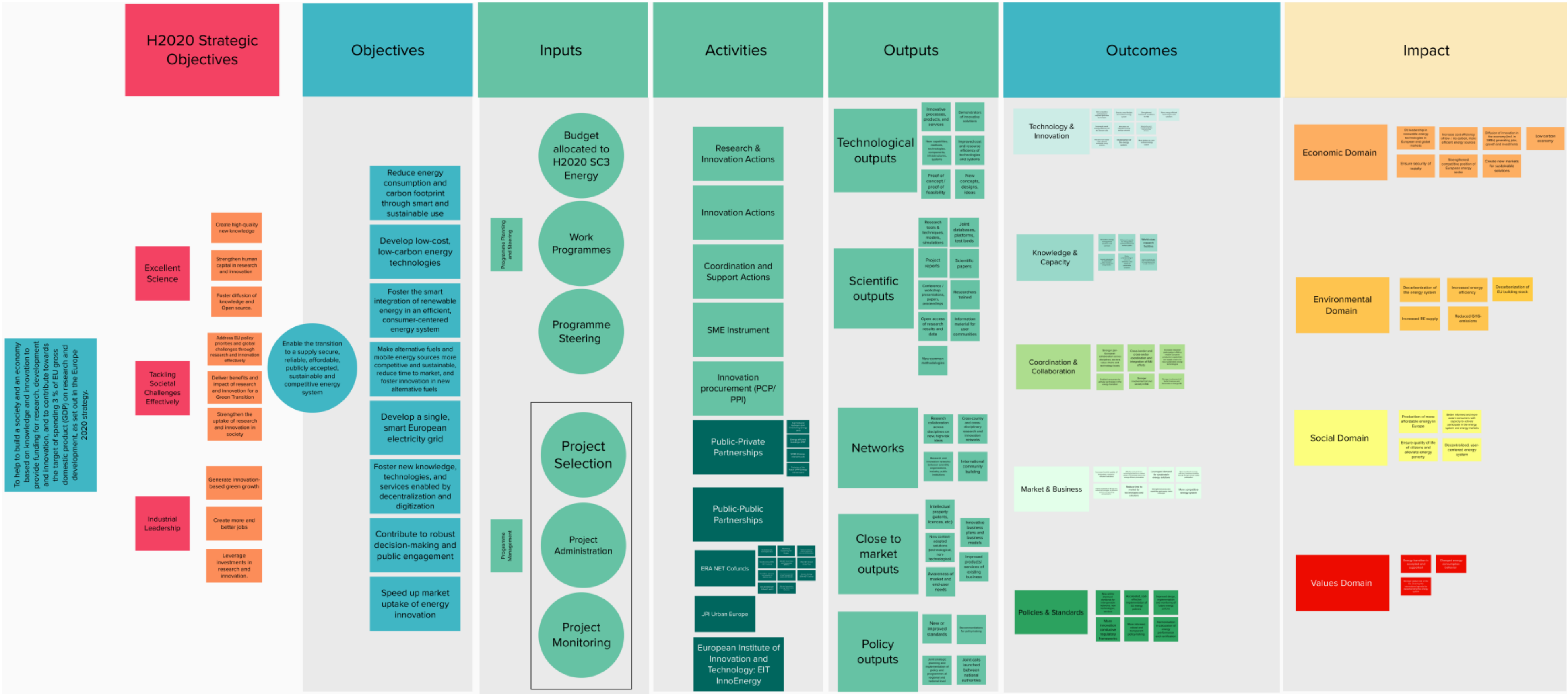


Figure 8. SC 3 – Secure, clean and efficient energy Intervention Logic.

Source: Own illustration

4.1. Objectives for SC 3 – Secure, clean and efficient energy

The general objective of SC 3 is to enable the transition to a supply-secure, reliable, affordable, publicly accepted, sustainable and competitive energy system. Based upon this overarching objective, Specific objectives for SC 3 Energy are:

- Reduce energy consumption and carbon footprint through smart and sustainable use
- Develop low-cost, low-carbon energy technologies
- Foster the smart integration of renewable energy in an efficient, consumer-centred energy system
- Make alternative fuels and mobile energy sources more competitive and sustainable, reduce time to market, and foster innovation in new alternative fuels
- Develop a single, smart European electricity grid
- Foster new knowledge, technologies, and services enabled by decentralization and digitization
- Contribute to robust decision-making and public engagement
- Speed-up market uptake of energy innovation

To achieve these goals, the interventions funded within SC 3 combine very different approaches including technological and social innovations and market uptake activities, as well as user and consumer behaviour. Therefore, the number of stakeholders involved is very large. The first work programme of the Horizon 2020 Energy Challenge mainly contributed to three focus areas "Energy Efficiency", "Competitive Low-Carbon Energy" and "Smart Cities and Communities". Activities cover the full innovation cycle from 'proof of concept' to applied research, pre-commercial demonstration, and market uptake measures. In the first years of H2020, the focus has evolved from improving specific technologies and their components to their smart integration in an efficient, consumer-centred energy system. A stronger focus on consumer integration and citizen-centred energy systems, as well as system integration, including storage technologies, emerged in the work programme 2016-2017, while additional themes such as the deployment of innovative energy services enabled by decarbonization, decentralization, and digitization were established toward the end of H2020.

4.2. Inputs and activities for SC 3 – Secure, clean and efficient energy

A total budget of EUR 5.02 billion was allocated by the EC to SC 3 projects since 2014, resulting in a total of 1123 projects. One Art. 187 partnership was partly financed through SC 3 (Fuel Cells and Hydrogen) with around EUR 375 million, resulting in 89 projects. Other public-private partnerships with relevance to SC 3 objectives, although not directly financed through SC 3, included energy-related activities undertaken by the Energy efficient buildings cPPP, SPIRE, and Factories of the Future (FoF) cPPP.

Public-public partnerships were an important part of SC 3 activities. In addition to the EIT KIC InnoEnergy, the Joint Programming Initiative Urban Europe (JPI UE) established activities and calls with relevance to the energy transition. Additionally, 12 ERA-NET Cofunds were funded by SC 3: Accelerating CCS technologies (ACT), Bioenergy Sustaining the Future, European joint programming initiative on smart energy systems for regions & local communities (EN SGplusRegSys), Geothermica, ERA-NET Smart Cities and Communities (ENSCC), ERA-NET Smart Grids Plus (EN SG+), DemoWind – delivering cost reductions in offshore wind, Joint programming actions to foster innovative CSP solutions (CSP), Ocean Energy ERA-NET Cofund, SOLAR ERA-NET Cofund 1 and 2, ERA-NET Digitalization of Energy Systems and Networks (EnerDigit).

4.3. Expected outputs for SC 3 – Secure, clean and efficient energy

The direct outputs of these projects cover a wide range of subjects which can be grouped under five headings. Due to the large number of calls and projects in SC 3, these are described in rather generic terms.

- **Technological Outputs**: Starting with new concepts, designs and ideas, projects have also produced new technical capabilities, methods, technologies, components, infrastructures, and systems, leading to demonstrators of innovative solutions and innovative processes, products and services for energy. They have improved the cost and resource efficiency of technologies and systems. Proof of concept and proof of feasibility of new renewable or low-carbon energy technologies, as well as integrated and systemic solutions supporting the integration of renewable energy sources into the energy system, have been developed.

- **Scientific outputs**: Projects' scientific outputs include project reports, scientific papers and presentations in conferences and workshops. They also include enhanced research tools and techniques, models and simulations, new common methodologies as well as joint databases, platforms and test beds. Project outputs also include information material for user communities, while research results and data have been provided in open access and researchers have been trained.

- **Networks**: New and strengthened research and innovation networks have been created between scientific organizations, industry and public institutions initiating collaboration across disciplines and countries on new, high-risk ideas. Furthermore, international community building was a key desired output.

- **Close to market outputs**: Outputs with a higher technology or market readiness include intellectual property (patents, licences, etc.), innovative business plans and business models as well as new context-adapted technological and non-technological solutions. These outputs also include improved awareness of market and end-user needs and should help existing businesses to adapt and improve their business.

- **Policy outputs**: Recommendations for policy-making and as well as contributions to new or improved standards are important policy-related outputs. On the level of public sector collaborations, joint strategic planning and implementation of policy and programmes at regional and national levels as well as joint calls launched between national authorities are other policy outputs expected within the area.

4.4. Expected outcomes for SC 3 – Secure, clean and efficient energy

Outcomes are expected in five complementing areas. These results are more specific to the energy societal challenge.

- **Technology and innovation**: Expected outcomes comprise more competitive, performant and integrated renewable energy generation technologies as well as new and more mature, clean, safe and sustainable technologies and solutions. Furthermore, projects are expected to contribute to a smarter, more flexible and resilient energy system, including by developing affordable and integrated storage solutions, developing solutions for the digitalization of the energy system, as well as approaches towards a more bottom-up, user-centred system. In addition, expected outcomes related to energy efficiency include more energy-efficient technologies and solutions and increased energy efficiency on the demand side, including by reducing the cost of renovations. In addition, SC 3 activities are expected to lead to strengthened framework conditions for sustainable energy-related R&I.

- **Knowledge and capacity**: Projects funded under SC 3 are expected to allow access to knowledge and contribute to a better understanding of complex energy systems and socio-economic contexts of the energy transition, consumer behaviour and uptake of sustainable solutions as well as enhanced capacity for energy policy implementation and uptake. Additionally, projects are expected to contribute data and knowledge for innovative energy management solutions and services as well as world-class research facilities and improve the knowledge and skills of the workforce related to energy efficiency,

- **Coordination and collaboration:** Expected outcomes are a stronger pan-European collaboration across disciplines, sectors, value chains and technology levels in general and improved cross-border and cross-sector coordination and integration of research and innovation efforts in particular. Additionally, a focus is also on increased industrial participation in R&I efforts to enable European production capabilities and supply chains, as well as a stronger involvement of civil society and consumers to enable active participation in the energy transition. This holds also true for the integration of Social Sciences and Humanities in Energy R&I, which should lead to improved integration of customer needs and behavioural change of energy system actors.

- **Market and business:** SC 3 aims at keeping the energy industry competitive while transitioning towards more sustainable energy sources. Therefore, results are expected to manifest in a more competitive industry, strengthened production capabilities and supply chains in Europe while leveraging demand for sustainable energy solutions and providing higher availability of renewable energy and low-carbon technologies for different markets and operating environments. Projects are expected to reduce time to market for innovative technologies and solutions and increase market uptake for innovative, resource-efficient solutions through, inter alia, the effective removal of non-technological barriers. Some projects are expected to contribute to more investment in energy efficiency investment markets by increasing the participation of private capital.

- **Policy and standards:** More informed, robust and transparent energy policies, including the improved design, implementation and monitoring of future energy policies, as well as the accelerated, cost-effective implementation of EU energy policies are expected outcomes in this domain. Furthermore, more innovation conducive regulatory frameworks, new and/or improved standards for networks, technologies, and services as well as the better harmonization of energy performance calculation and certification are expected.

4.5. Expected impacts for SC 3 – Secure, clean and efficient energy

Impacts are expected to be achieved in four areas – the economic, environmental, social and values domains.

- **Environmental domain**: Reflecting the overarching goal of this Societal Challenge, a decarbonized energy system is expected to have impacts including a reduction in CO2 emissions due to increased use of renewable energies and increased energy efficiency and decarbonization of the EU building stock. Furthermore, a reduction of water and soil pollution and contaminant should be enabled.

- **Economic domain:** In the economic domain, the EU is expected to take technological leadership and leadership in global markets for renewable energy technologies, with the diffusion of innovation generating jobs, growth and investment in the industry. Thus, more performant, cost-efficient energy sources that at the same time ensure the security of supply, meeting the growing energy demand. This goes along with the transition to a low-carbon economy, with the creation of new markets for sustainable solutions, and a strengthened competitive position of the European energy sector.

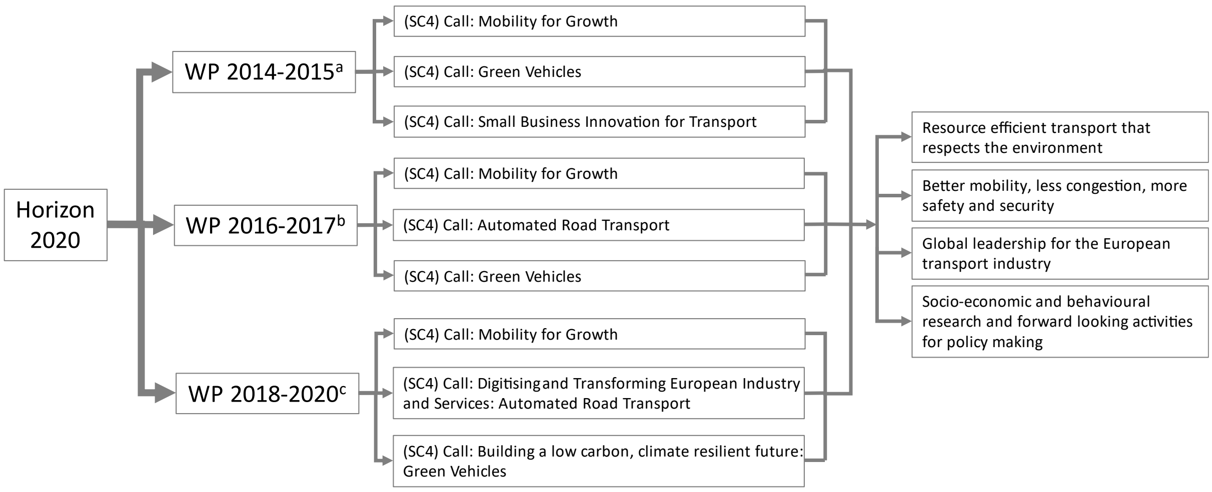
- **Social domain**: Expected impact in the social domain is a more decentralized, user-centred energy system that ensures the affordability of energy and the quality of life of citizens and alleviates energy poverty. This goes along with better informed and more aware consumers with the capacity to actively participate in the energy system and energy markets.

- **Values domain**: Impacts in the values domain is expected to be a publicly accepted and supported energy transition, where energy consumption behaviours are changed across all sectors of the economy and the wider public. A stronger global role of the EU in steering the international agenda for decarbonizing the energy system is also expected.

5. Societal Challenge 4 “Smart, green and integrated transport”

The specific needs put down for Societal Challenge 4 are “meeting Europe's mobility needs while reducing pollution, noise and greenhouse gas emissions, maintaining and increasing competitiveness and industrial leadership”. To address these needs the specific objective for the Transport Challenge when put into place in 2013 has been “to achieve a European transport system that is resource-efficient, climate and environmentally friendly, safe and seamless to the benefit of all citizens, the economy and society”60.

The figure below shows how Horizon 2020's work programmes have progressed through their respective calls for SC 4 during 2014-2020. The objectives have remained constant over the years. An indication is also provided where SC 4 has contributed to other societal challenges and their calls within Horizon 2020.



[a] **WP 2014-2015** includes contribution of the Transport Challenge to SME Instrument.
[b] **WP 2016-2017** includes contribution of the Transport Challenge to SME Instrument and Fast Track to Innovation Pilot.
[c] **WP 2018-2020** includes contribution of the Transport Challenge to selected (Cross-cutting) Calls – ‘Building a low-carbon, climate resilient future: Next-Generation Batteries’ and ‘Building a low-carbon, climate resilient future: Research and innovation in support of the European Green Deal’

Figure 9. Horizon 2020 SC 4 Calls and their WP focus/ priority areas.

Source: Own illustration.

In transport historically there were three pillars, namely safety, competitiveness, and greening. The objectives at the beginning of H2020 had a stronger focus on growth and well-being, but not to the same extent on environmental aspects. Moving from WP to WP there is an increase in 'green' topics. and there is a move away from the strict division by transport modes (within Mobility for Growth) from WP 2018-2020. More systemic issues are being addressed and there is also an increase in coverage of socio-economic topics in societal drivers, citizens' needs, mobility drivers and behaviour. There is now a paradigmatic shift in policy from H2020 to HE to a more environmental and sustainable approach. Avenues in research and innovation already taken were reinforced in new strategies and put under the umbrella of climate change and sustainability, particularly in the transport sector. This is seen as a much more coherent approach with a stronger policy drive.

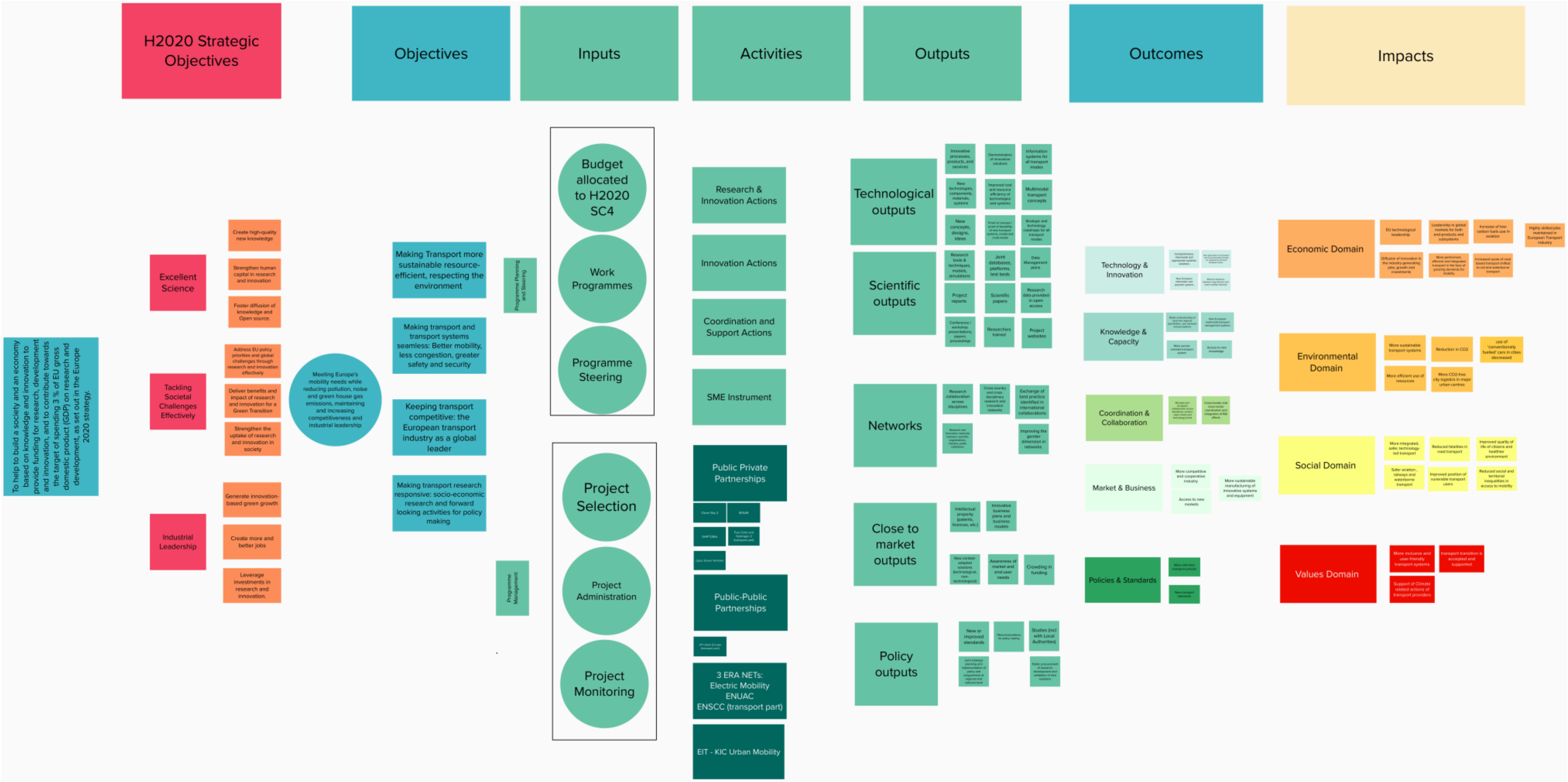


Figure 10. SC 4 – Smart, green and integrated transport intervention logic.

Source: Own representation

5.1. Objectives for SC 4 – Smart, green and integrated transport

Specific objectives for SC 4 Transport and Mobility are[20]:

- Making transport more sustainable: resource-efficient transport that respects the environment.
- Making transport and transport systems seamless: better mobility, less congestion, greater safety and security.
- Keeping transport competitive: the European transport industry as a global leader.
- Making transport Research responsive: socioeconomic research and forward-looking activities for policy-making.

To achieve these goals, the interventions funded within SC 4 combine very different approaches including technological and social innovations and market opportunities, or user behaviour. Therefore, the number of stakeholders involved is very large.

5.2. Inputs for SC 4 – Smart, green and integrated transport

A total budget of EUR 5.7 billion was allocated by the EC to SC 4 projects since 2014. About half of the EC contribution is dedicated to Art. 187 Partnerships (EUR 2,8 billion). Four partnerships have been financed (Shift2Rail, Fuel Cell and Hydrogen[2], Clean Sky 2, SESAR). Projects inside these partnerships account for 48 per cent of all SC 4 projects.[3] Establishing the co-programmed partnership Green Vehicle Initiative is described as an important change towards emphasizing green transition. The importance of the SME instrument is also significant in SC 4, representing about 26 percent of all projects with only 3 percent of the budget. In Transport area two, ERA-Net Cofunds on Urban Accessibility and Connectivity (EN-UAC) and Electric Mobility (EMEurope) are financed. Looking at the types of actions, innovation actions predominate in partnerships, while research and innovation actions predominate outside partnerships in the SC 4 WP.

5.3. Expected outputs for SC 4 – Smart, green and integrated transport

The direct outputs of these projects cover a wide range of subjects which can be grouped under five headings. Due to the large number of calls and projects in SC 4, these are described in rather generic terms.

- **Technological Outputs**: Starting with new concepts, designs and ideas, projects have also produced new technologies, components, materials and systems, leading to demonstrators of innovative solutions and innovative processes, products and services for transport and mobility. They have improved the cost and resource efficiency of technologies and systems. Proof of concept and proof of feasibility of new transport systems, modal and multi-modal solutions and transport concepts have been developed as well as information systems covering all transport modes. Also, strategic and technology roadmaps for all transport modes are among the technological outputs of SC 4 projects.
- **Scientific outputs**: Projects' outputs include project reports, scientific papers and presentations at conferences and project websites. They also include enhanced research tools and techniques, models and simulations as well as joint databases, platforms and test beds as well as plans to manage data. Research has been provided in open access and researchers have been trained.
- **Networks**: New and strengthened research and innovation networks have been created between scientific organizations, industry and public institutions initiating collaboration across disciplines

[20] Regulation (EU) No 1291/2013 of the European Parliament and of the Council of 11 December 2013 establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020) and repealing Decision No 1982/2006/EC

and countries. Best practice identified in international collaborations is being exchanged, including improving gender dimensions in networks.

- **Close to market outputs**: Outputs with a higher technology or market readiness include intellectual property (patents, licences, etc.), innovative business plans and business models as well as new context-adapted technological and non-technological solutions. These outputs also include improved awareness of market and end-user needs as well as new forms of funding.

- **Policy outputs**: Recommendations for policy-making and joint strategic planning and implementation of policy programmes at regional and national levels are important policy-related outputs. Policy outputs also include studies with local authorities, new processes of public procurement of research, development and validation of new solutions and new or improved standards.

5.4. Expected outcomes for SC 4 – Smart, green and integrated transport

Outcomes are expected in five complementing areas. These results are more specific to the transport and mobility societal challenge.

- **Technology and innovation**: Expected results comprise comprehensive, intermodal and appropriate systemic solutions, efficient interfaces between long-distance and urban mobility networks as well as new European information and payments systems; specific outcomes relate to a new generation of innovative and environmentally friendly air, waterborne and land transport means.

- **Knowledge and capacity**: Projects funded under SC 4 are expected to allow access to knowledge and contribute to a better understanding of local and regional characteristics, user behaviour and perceptions, for a more service-oriented transport system and new European multimodal transport management systems.

- **Coordination and collaboration:** Expected outcomes are a stronger pan-European collaboration across disciplines, sectors, value chains and technology levels in general and improved cross-border and cross-sector coordination and integration of research and innovation efforts in particular.

- **Market and business:** SC 4 aims at keeping transport competitive. Therefore, results are expected to manifest in a more competitive and cooperative industry, with access to new markets. At the same time, the manufacturing of innovative systems and equipment is to become more sustainable.

- **Policy and standards:** More informed transport policies and new transport standards are expected outcomes in this domain.

Interviewees questioned the possibility of establishing direct links between outputs and outcomes. Even when the vast majority of funded projects have been very successful, which they believe is the case, translating this into changes in the transport sector is much more difficult. This link might be even less strong in the area of green transition since at the start of the programme sustainability was one objective among others but not the priority.

5.5. Expected impacts for SC 4 – Smart, green and integrated transport

Impacts are expected to be achieved in four areas – the economic, environmental, social and values domains.

- **Environmental domain**: Reflecting the overarching goal of this Societal Challenge, more sustainable transport systems are expected as impacts, with a reduction in CO_2 emissions due to more efficient use of resources. In urban centres and cities, a decrease in the use of conventionally fuelled cars is expected as well as more CO_2-free city logistics.

- **Economic domain:** In the economic domain the EU is expected to take technological leadership and leadership in global markets for both end-products and subsystems, with the diffusion of innovation generating jobs, growth and investment in the industry. Thus, a more performant, efficient and integrated transport system meets the growing demand for mobility. This goes along with an increase in low-carbon fuel use in aviation and an increased quota of road-based transport shifted to rail and waterborne transport. An additional impact is highly skilled jobs being maintained in the European transport industry.

- **Social domain**: Expected impact in the social domain is a more integrated, safer, technology-led transport. This goes along with reduced fatalities in road transport and safer aviation, railways and waterborne transport, with improved participation of vulnerable transport users. Overall, improvements in the quality of life of citizens and a healthier environment are expected as well as reduced social and territorial inequalities in access to mobility.

- **Values domain**: Impacts in the values domain are expected to be more inclusive and user-friendly transport systems. The transport transition is accepted and supported widely and there is support of climate-related actions of transport providers.

6. Societal Challenge 5 “Climate action, environment, resource efficiency and raw materials”

Climate change and sustainable development have been integrated into Horizon 2020 with an overall aim to support activities that can enable Europe's leadership in the development of new processes and technologies for sustainable development while responding to the challenge(s) of climate change.

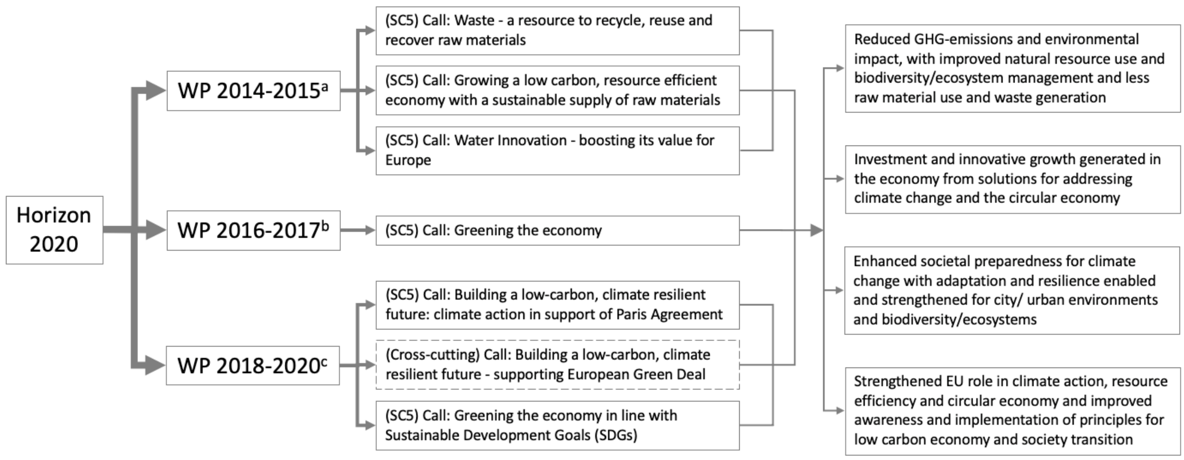
Horizon 2020 established climate action and sustainable development as a cross-cutting programme priority, and it is one of the issues mainstreamed in Horizon 2020. At least 60% of the overall Horizon 2020 budget was expected to be related to sustainable development, with climate-related expenditure forming 35% of the budget (including mutually compatible measures improving resource efficiency).

Climate action has been approached through a specific Societal Challenge in Horizon 2020, whereby SC 5 has the following overall objective (and as broadly laid down in Regulation (EU) No 1290/2013) to help respond to rising global population demands and within the sustainable limits of natural resources and ecosystems: Achieve a resource/ water efficient and climate change resilient economy and society, while protecting and sustainably managing natural resources and ecosystems and enabling sustainable supply and use of raw materials.

Horizon 2020's development and positioning on climate action were strongly influenced by the Europe 2020 strategy and its "20/20/20" targets and three mutually reinforcing priorities on smart, sustainable and inclusive growth (which sought to develop a knowledge and innovation-based economy with a more efficient, competitive and greener use of resources across a broad social and territorial 'map').

Horizon 2020's approach to climate change and sustainable development has also arguably had more of a focus on the challenges/ solutions for climate action when compared to the objectives of its predecessor, the seventh Framework Programme (FP7) and its cooperation theme on the environment (including climate change).

The figure below shows how Horizon 2020's work programmes have progressed through their respective calls for SC5 during 2014-2020 and in relation to the focal / priority areas of each work programme. An indication is also provided where SC5 has contributed to other societal challenges and their calls within Horizon 2020. NOTE: the cross-cutting Green Deal call is also included in this figure as part of the Work Programme 2018-2020.



[a] **WP 2014-2015** includes SC5 contribution to: (SC7) Call - Disaster-resilience: safeguarding and securing society, including adapting to climate change; (SC2) Call - Blue growth: unlocking the potential of the oceans; (SC3) Call - Energy-efficiency.
[b] **WP 2016-2017** includes SC5 contribution to: (cross-cutting) Call - Industry 2020 in the Circular Economy; Smart and Sustainable Cities; (SC2) Call - Blue growth – demonstrating an ocean of opportunities, Call - Sustainable Food Security – Resilient and resource-efficient value chains; (SC3) Call - Competitive low-carbon energy.
[c] **WP 2018-2020** includes SC5 contribution to: (Cross-cutting) Call - Competitive, Low Carbon and Circular Industries.

Figure 11. Horizon 2020 SC 5 Calls and their WP focus/ priority areas.

Source: Own illustration.

The first two Horizon 2020 work programmes for SC 5 (during 2014-2017) contributed towards the cross-cutting priorities of climate action and sustainable development and where, for example, as part of the implementation of the first SC5 work programme (2014-2015), waste as a resource and water innovation were both seen as key priority areas for focus due to the opportunities for business and job creation as well as the need to address resource efficiency.

During Horizon 2020's implementation over 2014-2020, the climate change and sustainable development priorities within the objectives of SC 5 are considered to have evolved through the sequence of its work programmes, progressively focusing on more systemic approaches. Two key areas have been highlighted to achieve those objectives. Firstly, climate change mitigation and adaptation and a focus on innovation and investment in climate research and green technologies. And secondly, the decoupling of economic growth and social development from resource exploitation and waste and focus on supporting a transition towards a circular economy.

Furthermore, the announcement of the European Green Deal by the Commission resulted in the Horizon 2020 final work programme (2018-2020) being amended through a European Green Deal Call. This Green Deal call has operated within the "Building a low-carbon, climate resilient future" Focus Area and through approaches for R&I and the applying science, knowledge and evidence.

The Focus Area on "Building a low-carbon, climate resilient future" has covered the final Horizon 2020 work programme (2018-2020) actions that contribute to the goals of the Paris Agreement and its impacts are based on achieving the following:

- A direct contribution to the Commission's European Green Deal Communication, contributing directly to the EU's Recovery Plan for Europe.
- Operationalisation of Paris Agreement goals, through high-quality policy-relevant evidence from the scientific community.
- Acceleration of transformation towards carbon neutrality, through co-design, co-development and co-deployment of technologies and services by researchers, entrepreneurs and citizens.
- Enhanced climate resilience in Europe and beyond, in sectors such as health, infrastructure, water, agriculture and forestry, as well as in cities.
- Long-term mitigation and adaptation policy planning, deployment of technology to reduce emissions and enhanced climate change resilience in developing countries.

SC 5 has formed a key component of this Focus Area and the final work programme (2018-2020) provided a specific Call on "Building low-carbon, climate resilient future - climate action in support of Paris Agreement."

Furthermore, the Focus Area on Connecting economic and environmental gains - Circular Economy has been structured to 'consolidate' R&I initiatives towards the achievement of the SDGs, climate action and industrial competitiveness. It is linked to the Commission's adoption of the 2020 Circular Economy Package (CEP). The Focus Area contributes to the renewal of Europe's industrial capacities and towards boosting growth, in a world of resource constraints, aiming to deliver: 1) Measurable improvement in resource use efficiency and effectiveness (primary and secondary), including energy, 2) Measurable reduction in waste generation, environmental pollution and greenhouse gas emissions; transforming recyclable waste into a flourishing market of secondary raw materials, 3) Creation of competitive advantage for existing businesses, 4) Creation of new businesses opportunities, including disruptive innovation, 5) Enhancement of security of raw materials supply.

Against this background, an updated intervention logic comprising all Horizon 2020 work programmes (2014-2015; 2016-2017; 2018-2020) is provided in the figure below and set out in narrative form in the sections below.

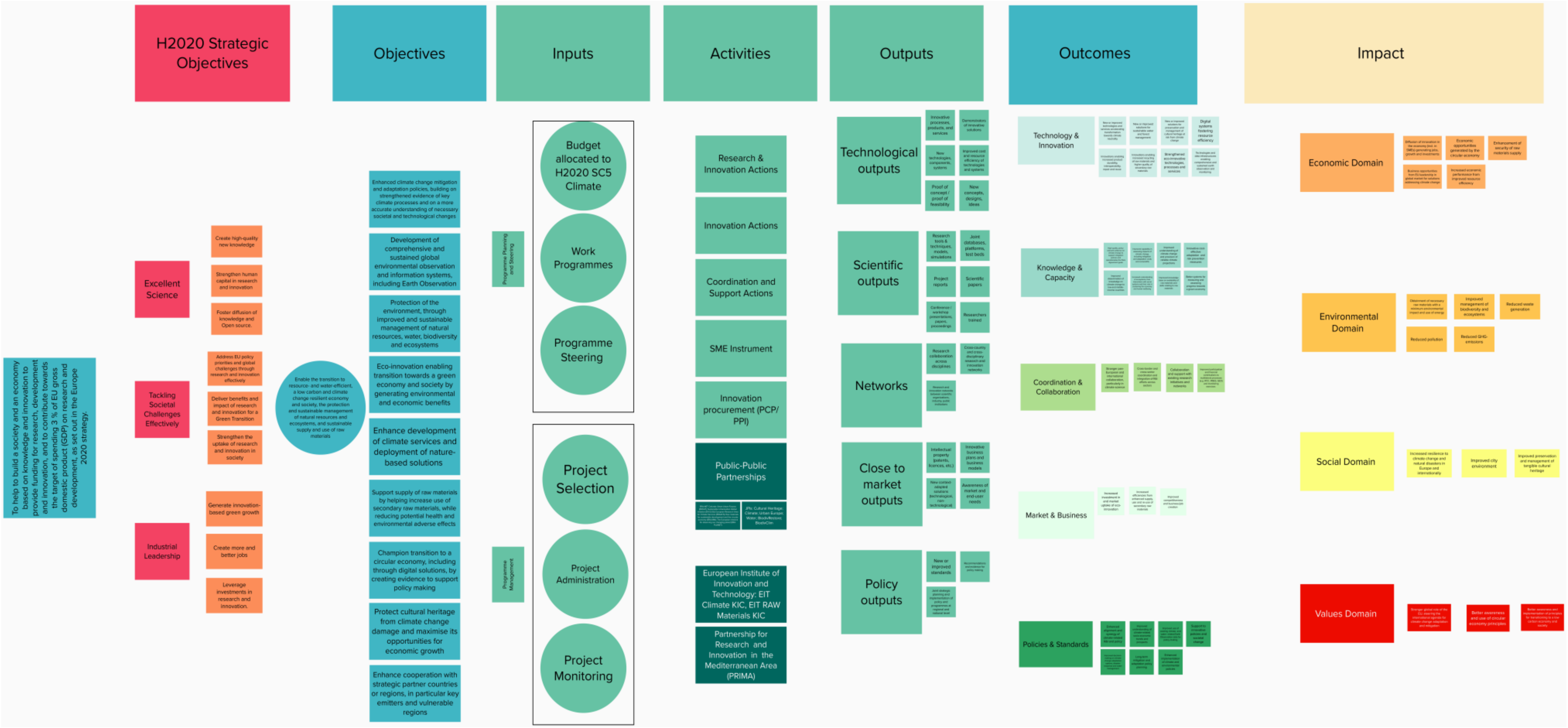


Figure 12. SC 5 – Climate action, environment, resource efficiency and raw materials intervention logic.

Source: Own representation

6.1. Objectives of SC 5 – Climate action, environment, resource efficiency and raw materials

The specific objectives of SC 5 (which have been set out within an updated intervention logic for SC 5 as part of this report) are seen as:

- Enhance climate change mitigation and adaptation policies, building on strengthened evidence of key climate processes and a more accurate understanding of necessary societal and technological changes.
- Develop comprehensive and sustained global environmental observation and information systems, including Earth Observation.
- Protect the environment, through improved and sustainable management of natural resources, water, biodiversity and ecosystems.
- Enable eco-innovation generating environmental and economic benefits to facilitate the transition towards a green economy.
- Enhance the development of climate services and deployment of nature-based solutions.
- Support the supply of raw materials by helping increase the use of secondary raw materials, while reducing potential health and environmental adverse effects.
- Champion the transition to a circular economy, including through digital solutions, by creating evidence to support policy making.
- Protect cultural heritage from climate change damage and maximise its opportunities for economic growth.
- Enhance cooperation with strategic partner countries or regions, in particular key emitters and vulnerable regions.

Within the overall aim of addressing the objectives of Horizon 2020 (Excellent science, tackling societal challenges effectively and industrial leadership), SC 5 has been focused through R&I-based actions on "enabling the transition to a resource/ water efficient, low carbon and climate change resilient economy and society, while also enhancing the protection and sustainable management of natural resources and ecosystems, and sustainable supply and use of raw materials." The specific actions (or activities) under SC 5 have been broadly focussed under:

- Climate action – informing decisions for a climate-resilient low-carbon society.
- Nature-based solutions – providing viable solutions for natural ecosystems.
- Circular economy – championing the transition towards a more sustainable use of natural resources, including raw materials and water.
- Systemic eco-innovation – generating and sharing economic and environmental benefits.
- Earth Observations – providing crucial evidence on climate, energy, natural hazards and other societal challenges.
- Cultural heritage – engaging a new cultural heritage agenda for economic growth.

6.2. Inputs for SC 5 – Climate action, environment, resource efficiency and raw materials

The activities through which the inputs and resources of SC 5 are channelled (through its work programmes, calls and programme management) have been structured to "contribute to increasing

European competitiveness and raw materials security and to improving well-being, whilst assuring environmental integrity, resilience and sustainability with the aim of keeping average global warming below 2°C and enabling ecosystems and society to adapt to climate change and other environmental changes."

A total budget of EUR 3.1 billion has been allocated by the EC to SC 5 projects since 2014 across the three work programmes. The EC contribution by start year of projects breaks down as follows: 2014-2015 (EUR 401 million); 2016-2017 (EUR 868 million); 2018-2020 (EUR 1099 million); 2021-after (EUR 804 million). Only a small amount of this EC contribution (EUR 25 million) has been dedicated to the Partnerships under Art. 187.

The 2018-2020 work programme for SC 5 indicated that the total budget anticipated for the Focus Area on "Building a low-carbon, climate resilient future" was EUR 4.7 billion and that the budget anticipated for SC 5 was EUR 868 million (18%). The anticipated contribution of the Call in support of the European Green Deal to this Focus Area is indicated as EUR 434 million. Whereas the total budget anticipated for the Focus Area on Connecting economic and environmental gains - Circular Economy was indicated as EUR 1.04 billion and the budget anticipated for SC 5 was EUR 360 million (34%), which included EUR 83 million in the cross-cutting Call on Competitive, Low-Carbon and Circular Industries. The contribution of the Call on Connecting economic and environmental gains - the Circular Economy to this Focus Area was noted as EUR 277 million.

Across the work programmes (and for the 2018-2020 work programme in particular), the predominant instrument focus appears to have been Research and Innovation Actions (RIA), Coordination and Support Actions (CSA) and Innovation Actions (IA).

ERA-NET Cofunds in scope for SC 5 financing have included: Smart Urban Futures (ENSUF); Sustainable Urbanisation Global Initiative (EN-SUGI); European Research Area for Climate Services (ERA4CS); Raw materials for sustainable development and the circular economy (ERA-MIN); The European network for observing our changing planet (ERA-PLANET). Joint Programming Initiatives (JPIs) in scope have included: Cultural Heritage; Climate; Urban Europe; Water; BiodivRestore; BiodivClim.

6.3. Expected outputs for SC 5 – Climate action, environment, resource efficiency and raw materials

The immediate results of the activities delivered/produced by SC 5 and its calls encompass a broad range of topics across technological, scientific and collaborative networks, market/end-user and policy outputs. These include the following:

- **Technological outputs:** The project calls within SC 5 have been structured to produce a broad range of technology-based outputs, such as innovative processes/ products/ services or new technologies/ components/ systems or demonstrators of innovative solutions. These include (as an indication) innovative nature-based solutions for carbon-neutral cities and improved air quality through Research and Innovation Actions as well as new technologies for the enhanced recovery of by-products and the demonstration of technologies for a water-smart economy/ society through Innovation Actions.

- **Scientific outputs**: Outputs through SC 5 have also been structured to include research tools & techniques, models and simulations as well as project reports, scientific papers and conference presentations and project websites. Research and Innovation Actions have been developed (and as an indication among others) to provide scientific support, evidence and analysis towards designing mitigation pathways and policies, and also to advance climate services by strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems.

- **Networks**: The establishment of new and enhanced networks and platforms for R&I have been included as part of an effort to develop improved collaboration across different disciplines, priorities and countries. For example, a project call within SC 5 (work programme 2018-2020) has been structured through a Coordination and Support Action to establish a joint platform which will formulate the R&I needs and priorities for circular economy development in the EU based on current research and produce a Strategic Research and Innovation Agenda.

- **Close to market outputs**: Outputs with a higher technology or market readiness would include intellectual property, innovative business plans and business models as well as new context-adapted technological and non-technological solutions.

- **Policy outputs**: The provision of expert support to and recommendations for policy-making, strategic planning and programming are an important component of SC 5, and the production of policy outputs encompasses recommendations and evidence for policy-making, joint strategic planning and implementation of policy and programmes at regional and national levels as well as new or improved standards. For example, a project call within SC 5 (work programme 2018-2020) has been structured through a Research and Innovation Action to support the development of climate policies to deliver on the Paris Agreement, through Integrated Assessment Models (IAMs).

6.4. Expected outcomes for SC 5 – Climate action, environment, resource efficiency and raw materials

The outcomes as early or medium-term (intermediate) results of the outputs produced by SC 5 are expected to be seen across the following five complementary themes:

- **Technology and innovation:** The expected outcomes of SC 5 and its projects include new/ improved technologies and services that accelerate the transformation towards climate neutrality as well as new/improved solutions for sustainable water and forest management and the preservation and management of cultural heritage at risk from climate change. In addition, the expected outcomes also include the development of digital solutions that foster resource efficiency and innovations that enable an increase in product durability, interoperability, repair and reuse and innovations that enable an increase in the recycling of raw materials and a higher quality of secondary raw materials. A strengthening/ enhancement of eco-innovative technologies, processes and services is also expected as well as the development of technologies and data infrastructures to help enable a more comprehensive and sustained earth observation and monitoring.

- **Knowledge and capacity:** The structure of the calls and projects under SC 5 are expected to allow access to knowledge and contribute to the development of high-quality, policy-relevant evidence on climate change to support mitigation policies and to an improved capability in assessing the impacts of climate change, including mitigation and adaptation costs and co-benefits. In addition, the expected outcomes include an improved capacity and understanding of climate change and more reliable climate projections and innovative cost-effective adaptation and risk prevention measures as well as improved dissemination of knowledge on climate change to low-and middle-income countries. An increased understanding of ecosystems, their interactions with social systems and their role in sustaining the economy and human well-being is also anticipated as well as an improved knowledge base on the availability of raw materials and skills relating to raw materials. Better capacity/ systems for measuring and assessing progress towards a green economy are also expected as an outcome of SC 5.

- **Coordination and collaboration:** The expected outcomes within the scope of coordination and collaboration capacity and capability include a stronger pan-European and international collaboration, particularly in climate science as well as improved cross-border and cross-sector coordination and integration of R&I efforts across sectors and with existing research initiatives and networks. An enhanced participation and financial contribution to multilateral processes (including IPCC, IPBES, and GEO) and monitoring exercises are also anticipated.

- **Market and business**: An increased level of investment in and market uptake of eco-innovation is expected as a result of the SC 5 calls as well as increased levels of efficiencies from enhanced supply, use and re-use of secondary raw materials and improved competitiveness and business/job creation.

- **Policy and standards**: An enhanced alignment and synergy of climate-related R&I and policy is expected as a result of SC 5 as well as an improved understanding of climate-related socio-economic trends and prospects and the use of existing climate- and water-related Earth Observation data for policymaking. Support for innovative policy development and societal change is also anticipated along with improved decision-making on climate change adaptation options, disaster response and water management and enhanced implementation of climate and environmental policies and long-term mitigation and adaptation policy planning.

6.5. Expected impacts for SC 5 – Climate action, environment, resource efficiency and raw materials

The impacts produced by SC 5 and the degree of systemic change expected to be seen across four high-level domains are set out below:

- **Environmental domain:** A contribution towards a reduction in the use of natural resources (e.g., critical or rare raw materials, water, energy), through obtaining the necessary raw materials with minimal environmental impact and minimal use of energy and waste generation. GHG emissions are expected to be reduced as a result of SC 5 as well as an improvement in the management of biodiversity and ecosystems.

- **Economic domain:** In the economic domain the EU is expected to take technological leadership and leadership in global markets for opportunities generated by the circular economy, as well as for broader solutions that address climate change. A contribution to the diffusion of innovation in the economy (incl. SMEs) generating jobs, growth and investments is also expected along with a contribution to the enhancement of security of raw materials supply and increased economic performance from improved resource efficiency.

- **Social domain:** A contribution to increased resilience to climate change and natural disasters in Europe and internationally is expected within the social domain as well as an improvement of the 'city/ urban environment and an improved preservation and management of tangible cultural heritage.

- **Values domain:** A stronger global role of the EU, helping steer and support the international agenda for climate change adaptation and mitigation is expected alongside a contribution to enhanced awareness and use of circular economy principles and to enhanced awareness and implementation of principles for transitioning to a low carbon economy and society.

ANNEX V: QUANTITATIVE DATA ANALYSIS

1. State of Play: Implementation of Horizon 2020

This section provides an analysis of the state of play in the four areas. For granted projects, the main indicators presented include the number and share of projects, investments (EC contribution and total cost of projects), and participation (including newcomers and SMEs). The main grouping categories used to support the following analyses were the societal challenges, type of instruments and actions, countries of funded organisations, and year of calls. Finally, for proposals, the success rate and oversubscription rate are presented desegregated by societal challenge and main action/instrument types.

Please consult Annex II for the detailed methodological specifications of the following analyses.

1.1. Overview

The tables reproduced in this section were based on the eCORDA database, which was provided to the evaluation group by the European Commission. This dataset includes information on proposals and projects supported by the EU's framework programmes. Some partnerships are not included in the main tables provided in this section for different reasons. For P2P partnerships (i.e., PRIMA, ERA-NET Cofund, EJP Cofund, and JPI), the tables are presented in a separate section below and were based on additional data provided by ERA-LEARN and the European Commission. This option was justified by the fact that the ERA-Learn data appeared to be more up to date, compared to eCORDA (e.g., eCORDA contains 83 PRIMA projects, while the ERA-LEARN database contains 129) and because eCORDA does not include proposal data for these projects. In the case of the EIT KICs, since it is structured in the form of activities (and not projects as the remaining H2020 projects), the indicators could not be produced to be included in this section.

The selection of relevant "green transition" projects was based on the H2020 topics related to the Societal Challenges (SCs) 2 to 5, as reported in the table "h20_ref_topic". Therefore, some topics (and projects) were attributed to multiple societal challenges and not to the unique societal challenge provided in the tables "project" or "proposal". Even though this attribution of some topics to more than 1 societal challenge appeared important to this analysis, given that many green transition projects may be relevant to multiple societal challenges, it should have, if any, a very limited impact on the final results, since only 25 topics were classified among more than 1 societal challenges (among the 2,144 topics included in any of the 4 societal challenges considered).

Projects funded under the SME instrument phase I were excluded from the present analysis (a total of 1,190 SME-phase I projects, or 23.9% of the "green transition" projects selected based on the criteria described above). This filter is intended to avoid biases that could have been introduced by the inclusion of these projects, which typically involved only 1 participant with EC contribution of EUR 50,000 (numbers that are very different from the average of the remaining projects reported in Table 2). In addition, to be excluded from the figures reported in this section, these projects will also be excluded from the remaining phases of this evaluation.

Error! Reference source not found. summarises the criteria to group H2020 topics across SCs. Most of the topics were assigned to a societal challenge using the primary societal challenge provided in eCORDA, or related to cases under Art. 187. The topics associated with the SC "Transport" included under Art. 187 are CleanSky 2 (550 topics), Shift2Rail (100 topics), SESAR (99 topics), and Fuel Cells and Hydrogen (46 topics). For the SC "Food", the Art. 187 partnership relates to bio-based industries. For SC "Energy" and SC "Climate", the Art. 187 topics refer to "Fuel Cells and Hydrogen".

Table 2. Number of H2020 topics (with projects) associated with societal challenges 2 to 5.

Societal Challenge	3.2. "Food"	3.3. "Energy"	3.4. "Transport"	3.5. "Climate"
Related to the Societal Challenge	350	346	989	201
Main societal challenge	241	263	191	189
Secondary societal challenges	8	2	3	6

Art. 187	101	81	795	6

NOTES:
- The row "Related to the SC" includes all topics that could be associated with a given societal challenge using the multiple assignments of topics to societal challenges from the table h20_ref_topic.
- The row "Main societal challenge" refers to the primary societal challenge linked to each project in the eCorda project table.
- The row "Secondary societal challenges" correspond to the other topics linked to a given societal challenge using the h20_ref_topic table not linked as the primary societal challenge.
- Art. 187 accounts for the projects under Article 187.
- This table excludes topics that only contain projects under the SME instrument phase 1.

The numbers should not be summed across societal challenges because some topics appear in multiple societal challenges.

Error! Reference source not found. presents the main indicators inferred from eCORDA, for each SC. Article 187 partnerships are highlighted in this table as these cases usually involved lower shares of EC contributions. P2P partnerships are excluded as explained above. Typically, the SCs "Food" and "Climate" are those that involved more participants per project (18 on average for both SCs), defined as the average number of organisations per project. Projects in "Energy" and "Transport" are those that involved a smaller number of participations per project, with an average of 13 and 14 (respectively) organisations per project (after excluding the partnerships).

The cost per project across SCs (after filtering out the partnerships) ranged from EUR 5.4 million ("Food") to EUR 6.4 million ("Climate"). The cost per project under the Art. 187 (the most common partnership) did not differ considerably compared to the non-partnership projects when all SCs are taken together (EUR 5.4 million for Art. 187 and EUR 5.7 million for the non-partnership projects). However, within SCs the differences were more pronounced. In SCs "Food" and "Energy", the total cost per project in Art. 187 exceed the cost of the remaining projects by more than EUR 2 million per project (EUR 3.4 million for "Food" and EUR 2.1 million for "Energy"). In the "Transport" area, which responded by most of Art. 187 projects, these projects involved a lower amount of euros per project (EUR 4.8 million in Art. 187 projects and EUR 5.7 million in the non-partnership projects), explaining the lower gap in cost between Art. 187 and WP projects when all 4 SCs were considered together.

Regarding the EC's contribution, projects under Art. 187 required a smaller contribution from the EC (as a percentage of the total cost of the projects) as these projects pool public and private funding. Overall, its contribution to Art. 187 projects were about 18% smaller compared to the remaining non-partnership projects.

FP7 projects were selected to benchmark each societal challenge. The selected FP7 projects include projects under the specific programme "Cooperation", excluding Article 187. The mapping of FP7 projects into societal challenges relied on a keyword approach in which the terms from titles and abstracts of these projects were semantically classified as relevant to one or more societal challenges. When looking at all societal challenges together, H2020, excluding Art. 187 and SMEs (the FP7 group did not include these types of projects), included more participation per project than FP7 (17 vs. 13). The total cost per project was not remarkably higher in H2020 compared to FP7, especially considering the increase in general prices between both programmes. The higher share of EC contributions observed for H2020, in comparison to FP7, is a result of the higher increases observed in EC contributions per project, in comparison to the total cost per project. Societal challenge "Energy" was the only one not observing a remarkable increase in participation per project, with only 1 additional participation per project (13 in FP7 to 14 in H2020). "Energy" was also a societal challenge with a lower increase in EC contributions per project (EUR 4.3 million to EUR 4.7 million). Finally, the shares of EC contribution increased considerably across all societal challenges.

Table 3. H2020 topics associated with societal challenges 2 to 5, number of projects, participation and cost.

Societal Challenge	Group	Nb Projects	Participants		Cost (EUR million)		EC contr. (EUR million)		Share EC contr.
			Nb	per project	Total	Per project	Total	Per project	
3.2. "Food"	Fp7 except Art. 187	844	12,458	15	5,049	6.0	3,495	4.1	69%
	H2020	687	12,076	18	4,144	6.0	3,538	5.1	85%
	Except Art. 187 and SME	463	10,061	22	2,764	6.0	2,603	5.6	94%
	Except Art. 187	545	10,169	19	2,928	5.4	2,716	5.0	93%
	Art. 187	142	1,907	13	1,216	8.6	822	5.8	68%
3.3. "Energy"	Fp7 except Art. 187	1,204	15,089	13	7,986	6.6	5,160	4.3	65%
	H2020	1,110	13,872	12	6,385	5.8	4,928	4.4	77%
	Except Art. 187 and SME	930	12,794	14	5,494	5.9	4,411	4.7	80%
	Except Art. 187	1,021	12,920	13	5,698	5.6	4,553	4.5	80%
	Art. 187	89	952	11	687	7.7	375	4.2	55%
3.4. "Transport"	Fp7 except Art. 187	626	8,109	13	3,819	6.1	2,477	4.0	65%
	H2020	1,434	14,861	10	7,360	5.1	5,707	4.0	78%
	Except Art. 187 and SME	458	7,876	17	3,026	6.6	2,690	5.9	89%
	Except Art. 187	574	8,032	14	3,273	5.7	2,861	5.0	87%

	Art. 187	860	6,829	8	4,087	4.8	2,846	3.3	70%
3.5. "Climate"	Fp7 except Art. 187	1,469	20,753	14	8,585	5.8	5,917	4.0	69%
	H2020	524	9,237	18	3,312	6.3	3,038	5.8	92%
	Except Art. 187 and SME	456	9,076	20	3,157	6.9	2,924	6.4	93%
	Except Art. 187	516	9,153	18	3,287	6.4	3,013	5.8	92%
	Art. 187	8	84	11	25	3.2	25	3.1	98%
Total (de-duplicated)	Fp7 except Art. 187	2,789	36,690	13	16,247	5.8	11,024	4.0	68%
	H2020	3,727	49,386	13	20,925	5.6	17,017	4.6	81%
	Except Art. 187 and SME	2,291	39,333	17	14,309	6.2	12,501	5.5	87%
	Except Art. 187	2,640	39,800	15	15,053	5.7	13,017	4.9	86%
	Art. 187	1,087	9,586	9	5,872	5.4	4,001	3.7	68%

NOTES:
- One participation is defined as the participation of one organisation in one project (i.e., if one organisation is involved in multiple projects, it counts as multiple participations, which is equivalent to the number of projects involving this organisation).
- All scores exclude SME instrument phase I and P2P projects.
- Partnerships cPPP are not presented separately as there was not an indicator in eCorda tables to promptly select these projects.
- Fp7: projects classified across societal challenges based on the affinity of keywords found in their titles and abstracts to each societal challenge. Restricted to the specific programme "Cooperation".

1.2. Evolution over time

Figure 13 below shows that the number of "Green Transition" projects per year of call was mostly stable across the 4 societal challenges (except for 2016, when the number of projects jumped from 469, in 2015, to 692). In 2016 the number of projects increased in the 4 societal challenges, followed by a decrease in 2017, when the number of projects per year returned to the yearly levels. Most of the projects included in this study will be completed at the end of the 4th year following their starting date (**Error! Reference source not found.Error! Reference source not found.**), and around 86% of them will be finished by 2023 (data not displayed).

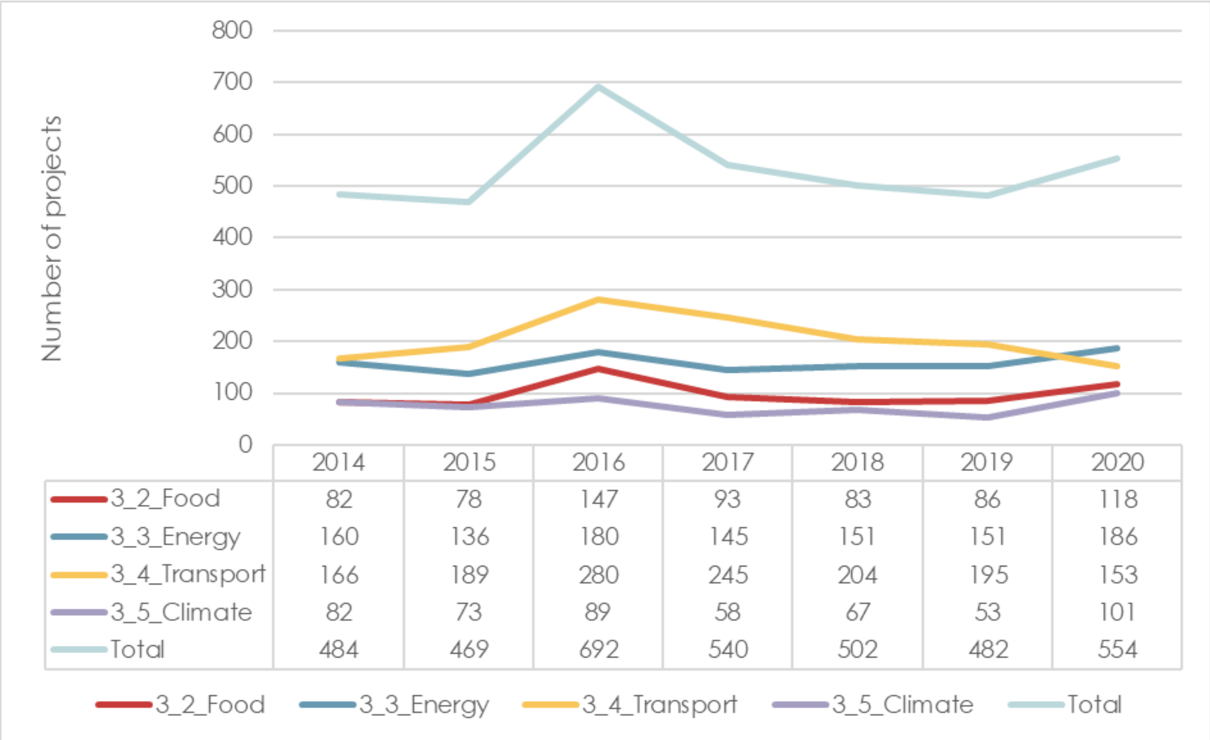


Figure 13. H2020 distribution of "Green Transition" projects by year of call.

Table 4. Share (%) of projects by number of years and societal challenge

Group of projects	Societal Challenge	Duration of projects (in years)						
		0	1	2	3	4	5	6+
Except partnerships	3.2. "Food"	1%	2%	17%	23%	41%	15%	1%
	3.3. "Energy"	0%	1%	17%	46%	25%	8%	1%
	3.4. "Transport"	0%	2%	25%	50%	21%	3%	0%
	3.5. "Climate"	0%	2%	14%	29%	44%	9%	2%

Art. 187	3.2. “Food”	0%	2%	7%	33%	30%	20%	9%
	3.3. “Energy”	0%	2%	21%	29%	19%	22%	6%
	3.4. “Transport”	0%	6%	33%	36%	16%	6%	2%

- Excludes SME instrument phase I and P2P projects.

The evolution of the EC contribution per project by year of calls (**Figure 14** below) shows that, on average, projects from earlier calls received lower levels of EC contribution. A project funded under a 2014 call received EUR 4.0 million, while a project from 2020 received EUR 5.9 million. The most significant increase was observed among “Climate” projects, which received an average of EUR 4.3 million in 2015 and EUR 8.2 million in 2020. Part of this increase can be explained by the changes observed in the shares of projects in each type of instrument (**Error! Reference source not found.**). The share of projects under Innovation Actions (IA) instruments increased from 20% in 2014 to 38% in 2020 for the 4 societal challenges considered together. As IA projects typically receive higher EC contributions on average, the increases observed in Figure 14 can be, at least partly, explained by higher shares of this type of project in the most recent years across the different societal challenges. Other factors may help to explain differences in the average EC contribution per project. For example, the number of participations per IA project increased by 109% in Food projects (from 10.8 in 2014 to 22.6 in 2020; data not shown) and may be another important factor to explain the variation in EC contribution observed for AI Food projects. European Commission study sponsors have told the study team that an explicit decision was taken in later H2020 calls to shift focus towards more highly funded and complex (in terms of team size) projects, notably through increased use of the Innovation Actions mechanism.

Table 8 provides a synthetic overview of shares of projects and EC contributions by SC for the full period. It notably highlights how shares of SC budgets and SC projects can be de-coupled, most notably in the case of SC3 CSA and IA budgets and project numbers as shares of SC3 overall budgets and project numbers.

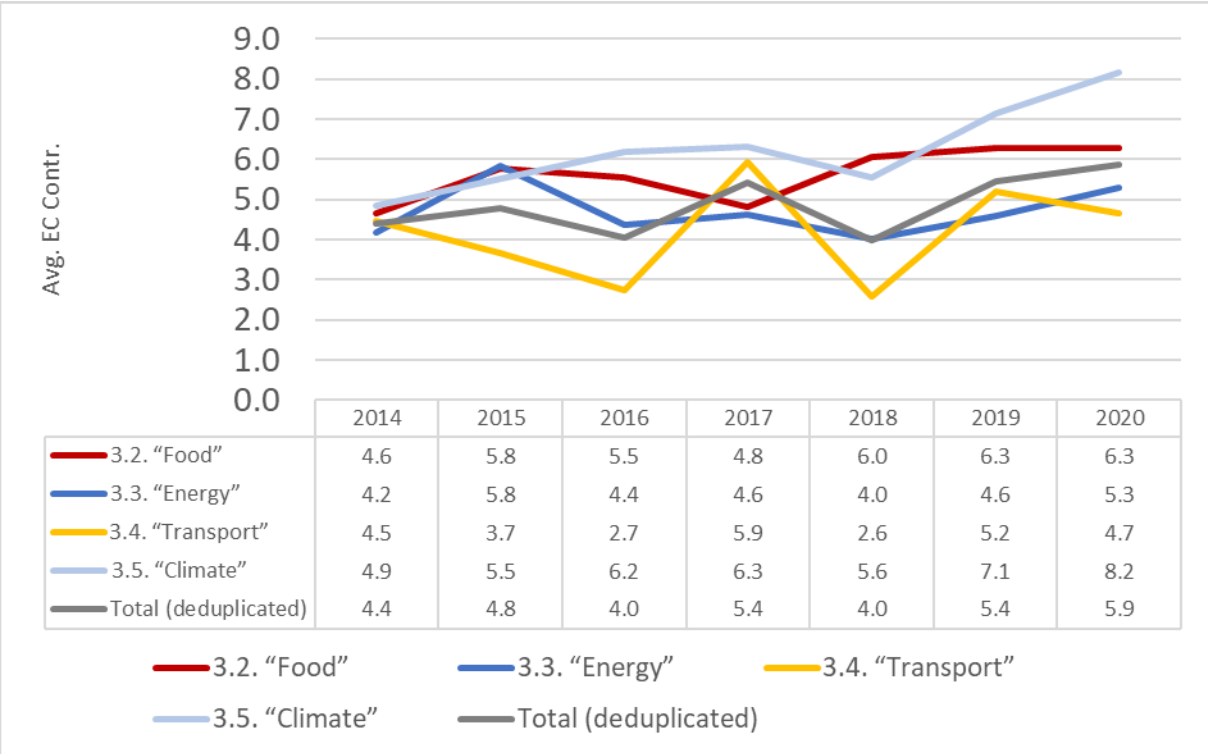


Figure 14. H2020 average EC contribution per "Green Transition" project by year of call.

Table 5. EC contribution per project by Societal Challenge, type of instrument and year.

Societal Challenge	Type of Instr.	average EC contribution per project							% of projects in societal challenge in the year						
		2014	2015	2016	2017	2018	2019	2020	2014	2015	2016	2017	2018	2019	2020
3.2. “Food”	CSA	2.1	1.7	1.8	2.2	2.6	2.3	2.1	24%	16%	12%	20%	23%	16%	19%
	IA	5.5	11.4	9.1	5.2	9.3	8.0	8.1	12%	15%	12%	29%	27%	36%	36%
	RIA	5.6	5.3	5.6	5.6	5.8	6.3	6.6	53%	44%	36%	48%	49%	44%	44%
	SME-II	1.4	1.6	1.3	N/A	N/A	N/A	N/A	10%	21%	38%	N/A	N/A	N/A	N/A
3.3. “Energy”	CSA	1.7	1.7	1.6	1.6	1.8	2.1	1.8	39%	34%	22%	32%	49%	39%	33%
	IA	9.6	16.1	9.6	8.2	9.5	9.2	10.0	20%	16%	14%	29%	19%	26%	33%
	RIA	3.7	5.1	4.0	4.4	4.2	3.8	4.0	28%	33%	32%	39%	32%	33%	33%
	SME-II	1.7	1.5	1.5	N/A	N/A	N/A	N/A	11%	14%	29%	N/A	N/A	N/A	N/A
3.4. “Transport”	CSA	1.2	2.6	1.7	1.3	1.2	2.0	1.5	9%	5%	6%	4%	8%	3%	9%
	IA	5.4	3.4	2.4	8.9	2.6	8.8	6.6	22%	26%	30%	49%	37%	33%	45%
	RIA	4.6	3.9	3.2	3.2	2.8	3.6	3.4	54%	58%	38%	46%	54%	64%	45%
	SME-II	1.4	1.5	1.5	N/A	N/A	N/A	N/A	14%	12%	25%	N/A	N/A	N/A	N/A
3.5. “Climate”	CSA	1.7	2.3	1.7	1.4	1.9	2.3	2.4	32%	16%	11%	23%	16%	11%	10%
	IA	4.9	6.8	8.0	9.9	8.4	9.3	11.6	20%	24%	25%	36%	16%	40%	38%
	RIA	8.2	6.0	6.3	5.9	5.8	6.4	6.6	30%	42%	22%	34%	67%	45%	49%
	SME-II	1.3	1.6	1.5	N/A	N/A	N/A	N/A	15%	14%	39%	N/A	N/A	N/A	N/A
Total (de-duplicated)	CSA	1.7	1.8	1.6	1.7	1.8	2.1	1.9	25%	17%	12%	17%	24%	17%	19%
	IA	6.8	7.5	5.3	8.4	5.6	8.8	8.8	20%	21%	22%	39%	28%	32%	38%
	RIA	5.0	4.6	4.1	4.2	4.1	4.4	5.0	41%	46%	34%	43%	48%	49%	42%
	SME-II	1.4	1.5	1.5	N/A	N/A	N/A	N/A	13%	14%	31%	N/A	N/A	N/A	N/A

Note: Excludes SME instrument phase I and P2P projects.

Table 6. EC contribution per project by Societal Challenge and type of instrument (2014-2020).

Action/Instrument	EU.3.2.		EU.3.3.		EU.3.4.		EU.3.5.	
	EC Contr	Projects	EC Contr	Projects	EC Contr	Projects	EC Contr	Projects
CSA	267	126	692	396	140	91	172	91
IA	1,321	166	2,550	255	2,863	501	1,367	153
PCP			21	2	3	1	5	1
RIA	1,837	313	1,523	366	2,530	725	1,405	219
SME-I	13	255	18	356	17	345	11	223
SME-II	113	82	141	91	172	116	89	60
Total table 2 - exclude SME - 1	**3,538**	**687**	**4,928**	**1,110**	**5,707**	**1,434**	**3,038**	**524**
Total CSA RIA IA (Art. 187 is included)	**3,424**	**605**	**4,766**	**1,017**	**5,533**	**1,317**	**2,944**	**463**
Shares among IA, CSA, RIA, PCP, SME-II (Includes Art.								

187 partnerships)								
CSA	8%	18%	14%	36%	2%	6%	5.7%	17%
IA	37%	24%	52%	23%	50%	35%	45.0%	29%
RIA	52%	46%	31%	33%	44%	51%	46.2%	42%
Total	**97%**	**88%**	**97%**	**92%**	**97%**	**92%**	**97%**	**88%**

1.3. Distribution of projects by country

The map in the figure next page highlights the countries involved in at least one H2020 project in the selected SCs. It shows that the programme involved organisations from most countries in the world. The map is reproduced for each of the SCs in **Figure 16** and shows that a larger number of “south” countries participated in the “Food” projects, while fewer “south” countries participated in the “Transport” projects. The table below shows the distribution of projects and participation by country to complement the information provided in the maps. The group of E27+UK countries was involved in more projects and with more participation per project, compared to the H2020 Associated Countries or the group "other". The group of other countries usually participated in a small number of projects per country (between 1.5 for "Energy" projects and 2.8 for "Climate" projects). Regarding the higher number of other countries involved in the "Food" projects, this was also where other countries achieved a larger number of participation and participation per project.

Table 7. H2020 projects by country group.

Group of country	Countries	Projects	Projects per country	Participation	Participation per project
3.2. “Food”					
EU27+UK-H2020	28	681	24.3	10,395	15.3
H2020 Associated	15	355	23.7	877	2.5
Other Countries	69	160	2.3	671	4.2
3.3. “Energy”					
EU27+UK-H2020	28	1102	39.4	12,434	11.3
H2020 Associated	14	444	31.7	978	2.2
Other Countries	62	95	1.5	266	2.8
3.4. “Transport”					
EU27+UK-H2020	28	1422	50.8	13,720	9.6
H2020 Associated	11	386	35.1	732	1.9
Other Countries	34	100	2.9	207	2.1
3.5. “Climate”					
EU27+UK-H2020	28	517	18.5	7,892	15.3
H2020 Associated	15	273	18.2	681	2.5
Other Countries	62	171	2.8	540	3.2

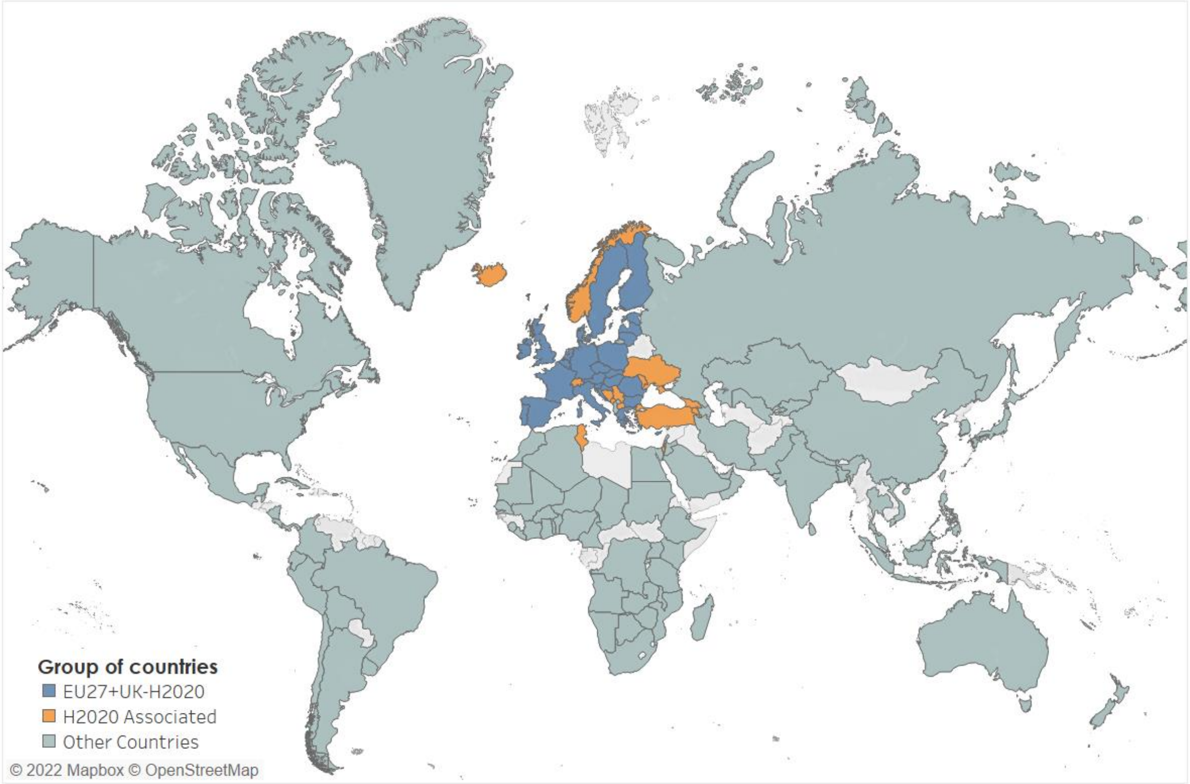


Figure 15. Countries of organisations funded by the H2020 programme (Societal challenges 2 to 5).

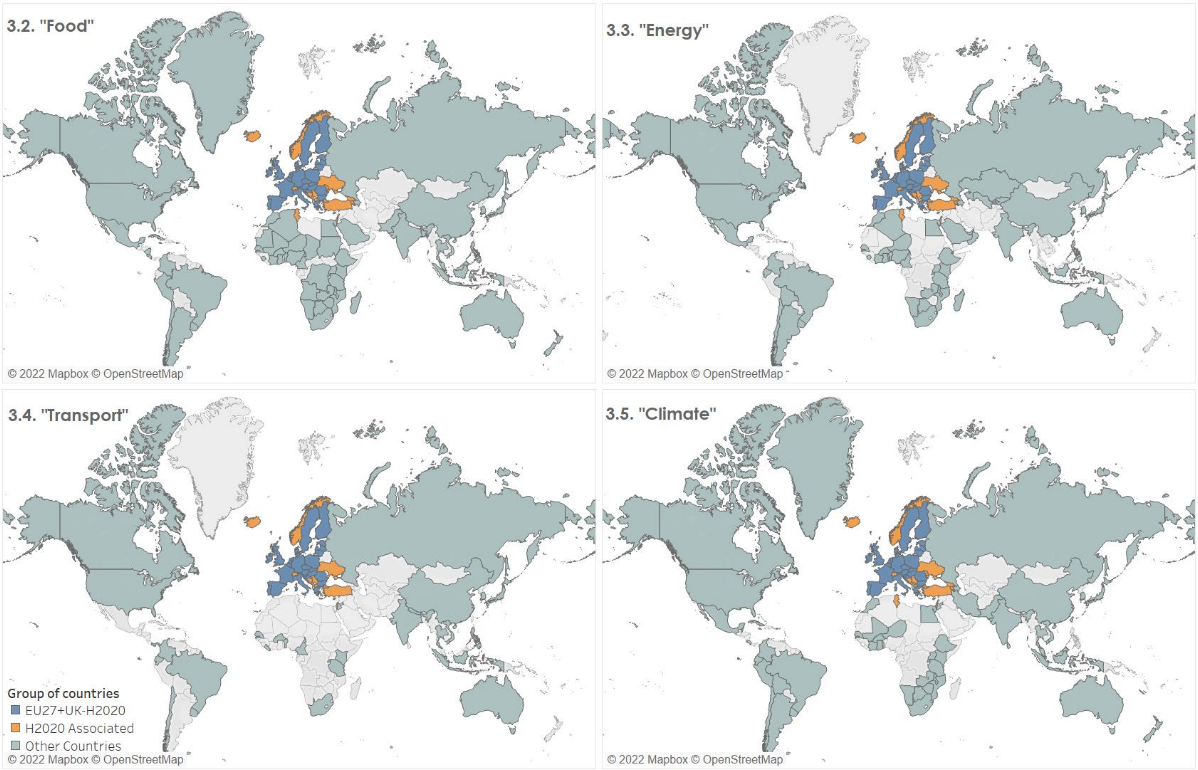


Figure 16. Countries of organisations funded by the H2020 programme (by societal challenge).

In the figure below, the group EU27 + UK countries is presented according to their H2020 EC contribution normalized by the country's GDP. Greece (EL) and Slovenia (SI) appeared among the fourth quartile in this indicator in the 4 societal challenges under analysis. Belgium (BE), Cyprus (CY), Estonia (EE), and Spain (ES) appeared in the fourth quartile in this indicator in 3 societal challenges.

The countries with larger GDPs (France, Germany, Italy, and the United Kingdom) figured in the lowest 2 quartiles in at least 3 of the 4 societal challenges. The annexe provides a similar analysis by looking at EC contribution per participation.

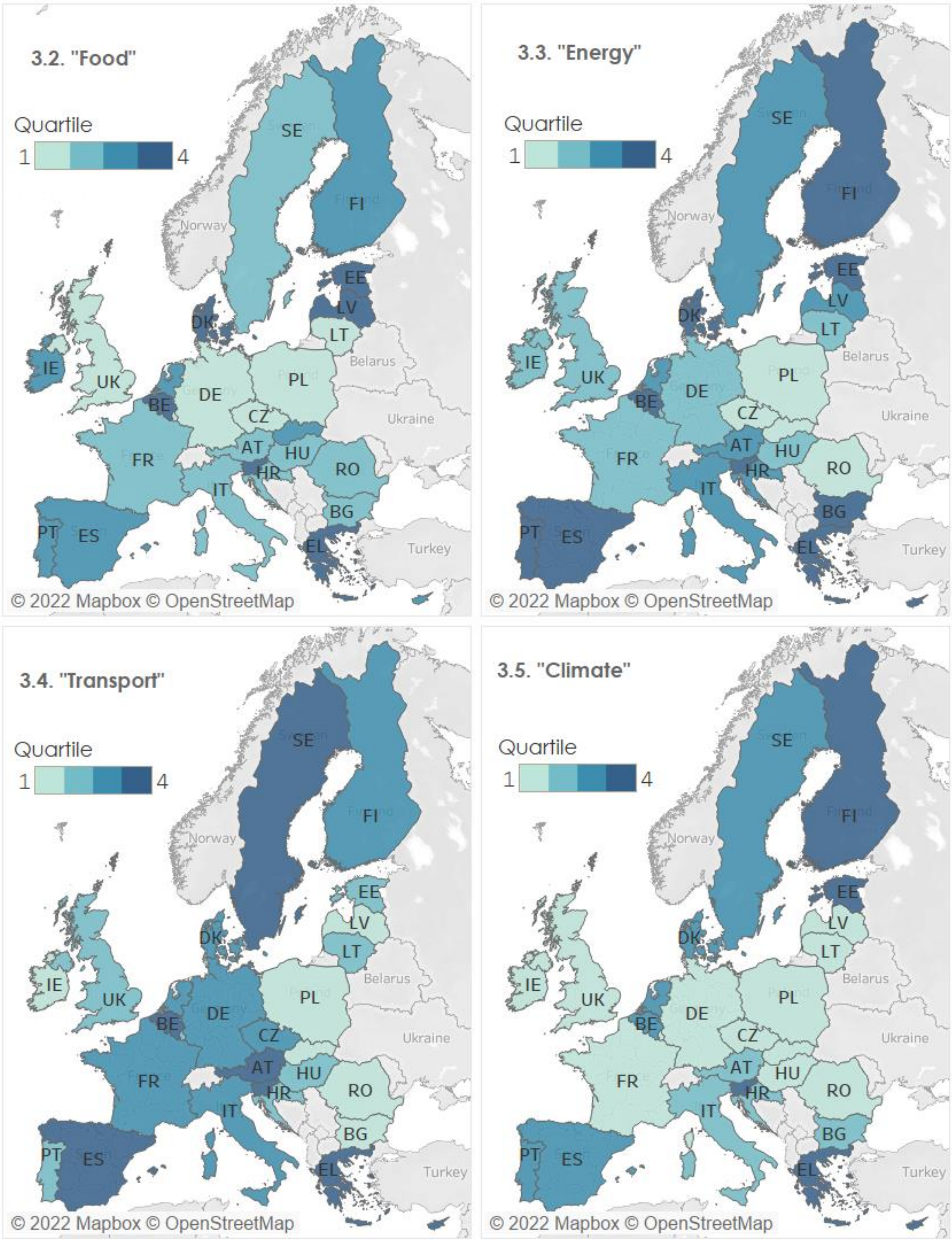


Figure 17. Countries (EU27 + UK) grouped by EC contribution normalised by GDP.

The figure below displays EU27+UK countries according to the respective EC contribution per participant country. Slovakia (EUR 542,000), Ireland (EUR 403,000), Finland (EUR 390,000), and Estonia (EUR 387,000) are the 4 countries with the highest EC contributions per participation in Food projects. In societal challenge Energy, Denmark (EUR 524,000), the United Kingdom (EUR 488,000), Germany (EUR 465,000), and Finland (EUR 461,000) are the top four countries in this indicator. France (EUR 520,000), Germany (EUR 486,000, the United Kingdom (EUR 451,000), and Finland (EUR 450,000) are those with higher amounts of EC contribution per participation in Transport projects. Finally, in societal challenge Climate, Germany (EUR 436,000), Netherlands (EUR 434,000), Sweden (EUR 421,000), and Finland (EUR 411,000) appeared among the top 4 countries in EC contribution per participation.

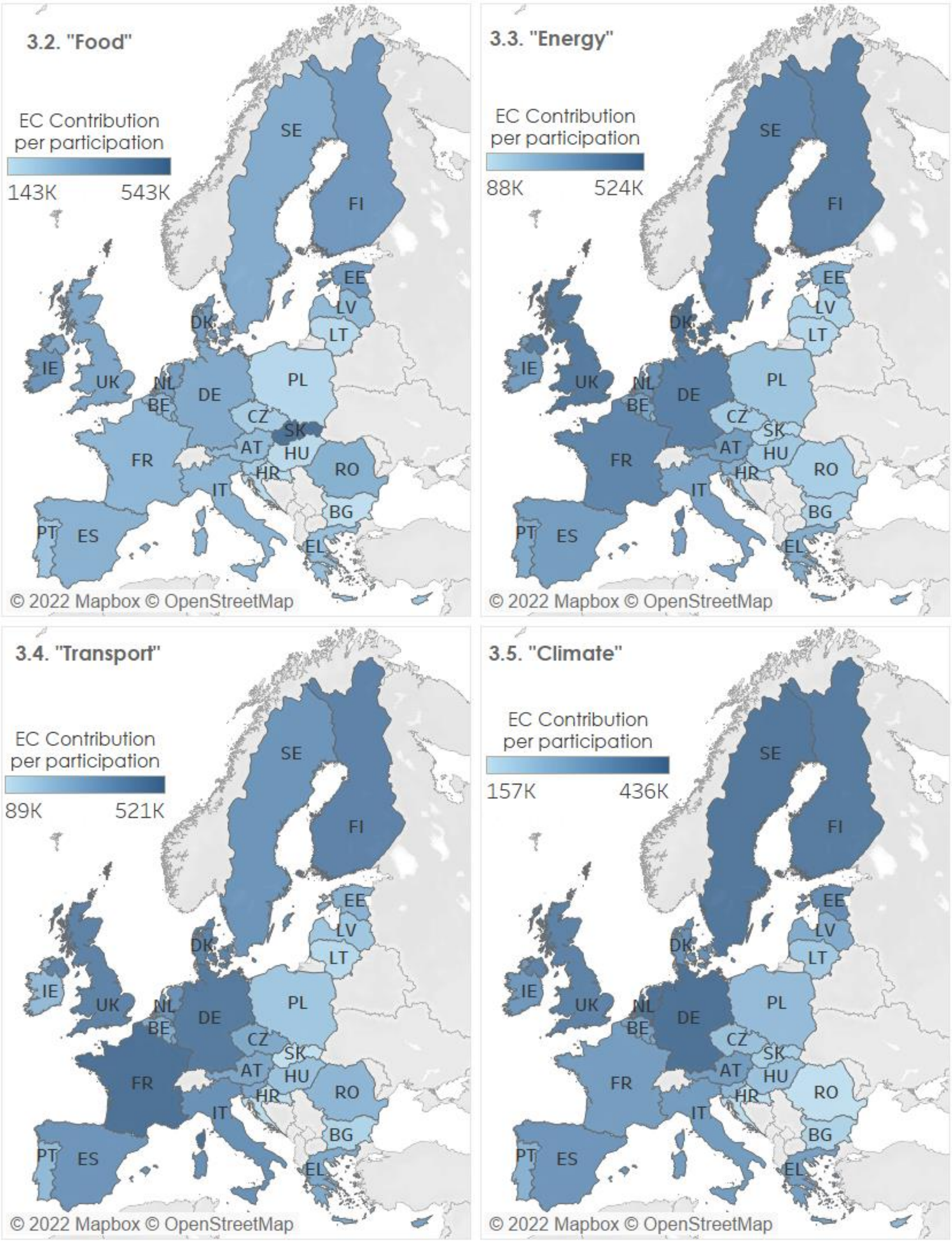


Figure 18. Countries (EU27 + UK) by EC contribution per participation.

1.4. Sectoral distribution of participants and projects

The table below shows the number of projects according to the activity type of the participant organisations in the projects for each SC. The number in parenthesis refers to the share of the projects in each SC that involved at least one organisation from a given type. Private organisations (PRC) were involved in around 90% of the projects in each of the four SCs. The share of projects involving Educational Establishments was similar to the share of projects involving Research Organisations, with the latter displaying slightly higher shares across the 4 societal challenges.

The column "Part. p. project" reports the average number of organisations (from each type) per project involving at least one institution of the same type. For example, the average number of private organisations across the 92% of "Energy" projects involving this type of organisation was 6.0. In the case of educational organisations (HES), an average of 2.9 educational organisations was observed in the 69% of "Energy" projects involving educational organisations. It shows that the higher "private" participation in "Energy" projects was not achieved by reducing the number of these organisations in projects. In fact, private participation per project (involving at least one private organisation) was higher than the average number of participations of any other organisation types in "Energy" and "Transport". For "Food" and "Climate", the average number of private participants is not too different from Educational and Research organisations, reinforcing the idea that the higher shares of projects involving private organisations observed in all SCs did not result from smaller average numbers of this type of organisation in projects (for example, if a large number of projects had involved only 1 private organization, the average number of private participation per project would be close to 1, while most projects would still involve private organisations). The shares of participation by organisational activity (data not shown in tables) also showed that the private sector responded with the highest participation share out of all SCs (33% of all participation in "Food" projects were private organisations, 46% in "Energy" projects, 57% in "Transport" projects and 32% in "Climate" projects; data not shown in the tables).

Table 8. Number of projects and participation per project by organisational sector (Activity).

Activity	3.2. "Food"		3.3. "Energy"		3.4. "Transport"		3.5. "Climate"	
	Projects	Part. p project	Projects	Part. p project	Projects	Part. p project	Projects	Part. p project
HES	538 (78%)	5.3	772 (70%)	2.9	918 (64%)	2.5	412 (79%)	5.1
PUB	258 (38%)	2.5	341 (31%)	3.1	303 (21%)	2.5	253 (48%)	3.4
REC	575 (84%)	5.7	859 (77%)	3.0	967 (67%)	2.6	446 (85%)	5.1
PRC	647 (94%)	6.0	1032 (93%)	6.0	1272 (89%)	6.5	473 (90%)	6.2
OTH	426 (62%)	3.0	593 (53%)	2.7	352 (25%)	2.1	307 (59%)	3.1

Notes:
Excludes SME instrument phase I projects.
The columns "Projects" report the number of projects involving at least one organisation of a given activity (in parenthesis, the number of projects as a share of all projects of the same Societal Challenge).
Part. p project: the number of participations per project refers to the average number of organisations from the given type in projects involving at least one organisation of the same activity.

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

The table below provides the share of projects involving at least 2 sectors. It compares these shares for societal challenges excluding partnerships, each of the 2 partnerships included in eCorda, and the FP7 projects thematically associated with each societal challenge. Societal challenge 4 displayed the lower share of projects with participants from at least three distinct sectors (71%, when partnerships were excluded), while the other three societal challenges exhibited shares that were close to 80% (also excluding the partnerships). This table excludes the SME phase II instrument from H2020 projects, as these cases only include private participants, which would artificially reduce the H2020 scores on intersectoral collaboration. In societal challenges 2 and 3, the shares of projects involving at least 2 sectors are similar between partnerships and non-partnership projects, with almost all projects involving at least 2 sectors. The non-partnership projects scored higher when the indicator was restricted to at least 3 sectors (the exception was for the share of projects involving 5 sectors in societal challenge 3, with both groups scoring 15%). In societal challenge 4, the difference between non-partnerships and partnerships was more accentuated, with non-partnerships exhibiting a higher share of projects involving at least 2 sectors (98% vs. 80%) with this difference increasing as more sectors were considered in the indicator. The number of partnerships in societal challenge 5 was too small to allow any conclusions.

Compared to Fp7 projects, H2020 (excluding partnerships and SMEs) was also associated with higher shares of projects involving multiple sectors. When at least 2 sectors were considered, the differences were small but when 3 or more sectors were required, H2020 projects exceeded Fp7 on cross-sectoral collaboration, with differences becoming more pronounced as the number of sectors increased. For example, the shares of projects involving all 5 sectors did not exceed 10% for Fp7 projects, while, for H2020, the scores range from 15% for societal challenge 3 to 39% for societal challenge 2.

Table 9. Number and Share of projects involving multiple sectors by societal challenge (H2020, partnerships, and FP7).

Societal Challenge	Programme	Group	N projects	Share of projects involving at least N sectors			
				2	3	4	5
3.2. "Food"	Fp7	Except Art. 187	844	98%	85%	36%	9%
	H2020	SC except part. and SME	463	99%	96%	79%	39%
	H2020	Art. 187	142	97%	80%	35%	5%
3.3. "Energy"	Fp7	Except Art. 187	1201	98%	83%	25%	6%
	H2020	SC except part. and SME	869	98%	86%	49%	15%
	H2020	Part. Art. 187 and cPPP	150	98%	79%	31%	15%
	H2020	Art. 187	89	97%	71%	8%	7%
	H2020	cPPP	61	100%	92%	64%	28%
3.4. "Transport"	Fp7	Except Art. 187	622	98%	83%	27%	7%
	H2020	SC except part. and SME	387	98%	93%	56%	24%
	H2020	Part. Art. 187 and cPPP	931	80%	45%	14%	4%
	H2020	Art. 187	860	78%	42%	13%	3%
	H2020	cPPP	71	100%	86%	24%	8%
3.5. "Climate"	Fp7	Except Art. 187	1469	98%	85%	35%	8%
	H2020	SC except part. and SME	455	97%	93%	71%	36%
	H2020	Part. Art. 187 and cPPP	9	100%	89%	0%	0%
	H2020	Art. 187	8	100%	88%	0%	0%
	H2020	cPPP	1	100%	100%	0%	0%

Notes:
The group of Fp7 projects was defined by applying keyword queries related to each societal challenge (restricted to projects classified under the "Cooperation" part of that programme). The total number of projects for this group is slightly smaller than those from **Error! Reference source not found.** because there were a few cases of missing sectors in Fp7 tables in eCorda.
The H2020 SC groups exclude both SME instruments (phase I and II, as these were specific to the private sector).

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

To complement the figures provided in the table above, the table below provides the share of participants by sector for the same groups provided in **Error! Reference source not found.** along with the share of collaborations involving each pair of sectors (e.g. HES-PUB refers to the collaborations in which one of the partners is a Higher or Secondary Education Establishments, and the other is a Public body). This table includes a considerable amount of data points as each possible type of intersectoral collaboration was included, but it can be summarized in a few main observations.

The main differences observed relate to the increased share of participation from other sectors in H2020, compared to FP7. Increases in participation from public bodies were also observed in societal challenges 3, 4, and 5. The remaining sectors observed moderated decreases or stability in their shares that offset the increases observed for public and other sectors. An effect of the changes in the share of participation in each sector can be observed in the shares of collaborations with other sectors. For example, the sector "other" also increased their shares of collaborations with other sectors which should be expected as higher shares of participation from other sectors were observed in H2020 in each societal challenge.

The comparison within the H2020 programme, between partnership and non-partnership projects, showed higher shares of participation from the private sector for all societal challenges (except for societal challenge 5, which does not have enough data points on partnerships to produce reliable figures). This complements the figures provided in the tables above since, with a higher concentration of participants in the private sector, one should expect lower shares of projects involving a high number of sectors (4 or 5, for example).

Table 10. Share of participation by sector and involving intersectoral collaboration for each pair of sectors (H2020, partnerships, and FP7).

Societal Challenge	Programme	Group	Sector	Share of participation	Share of collaboration with: HES	PUB	REC	PRC	OTH
3.2. “Food”	Fp7	Except Art. 187	HES	30.8%	11%				
			PUB	7.1%	3%	3%			
			REC	30.6%	20%	5%	11%		
			PRC	28.2%	14%	2%	14%	11%	
			OTH	3.3%	2%	1%	2%	2%	0%
	H2020	Societal challenge except partnerships and SME	HES	26.3%	7%				
			PUB	6.3%	3%	1%			
			REC	29.4%	15%	4%	9%		
			PRC	26.5%	12%	3%	14%	10%	
			OTH	11.5%	5%	2%	6%	6%	2%
	H2020	Art. 187	HES	12.4%	2%				
			PUB	0.8%	0%	0%			
			REC	18.2%	4%	0%	3%		
			PRC	61.3%	14%	1%	21%	41%	
			OTH	7.2%	2%	0%	2%	8%	1%
EU.3.3. “Energy”	Fp7	Except Art. 187	HES	23.2%	7.6%				
			PUB	3.9%	1.1%	1.2%			
			REC	22.7%	10.7%	1.7%	5.4%		
			PRC	47.6%	19.8%	2.8%	18.7%	25.4%	
			OTH	2.6%	1.1%	0.4%	1.1%	2.6%	0.2%
	H2020	Societal challenge except partnerships and SME	HES	16.8%	3.8%				
			PUB	8.2%	1.8%	3.2%			
			REC	18.6%	6.2%	2.7%	3.6%		
			PRC	43.6%	13.9%	5.9%	14.0%	25.8%	
			OTH	12.8%	2.4%	2.5%	3.5%	7.7%	2.8%
	H2020	Art. 187	HES	15.7%	2.7%				
			PUB	2.0%	0.6%	0.3%			
			REC	24.1%	6.4%	0.9%	6.1%		
			PRC	54.7%	10.8%	5.0%	17.8%	38.8%	
			OTH	3.4%	0.7%	0.9%	2.1%	5.9%	1.0%
	H2020	cPPP	HES	12.7%	1.5%				
			PUB	6.8%	2.0%	1.2%			
			REC	15.3%	2.9%	2.1%	1.9%		
			PRC	54.5%	12.5%	10.3%	14.2%	30.6%	
			OTH	10.8%	2.3%	2.4%	3.3%	11.0%	1.9%
3.4. “Transport”	Fp7	Except Art. 187	HES	21.4%	4.8%				
			PUB	4.4%	1.5%	1.1%			
			REC	23.4%	10.0%	2.1%	6.3%		
			PRC	47.8%	17.8%	3.8%	19.4%	27.0%	
			OTH	3.1%	0.9%	0.6%	1.2%	3.0%	0.3%
	H2020	Societal challenge except partnerships and SME	HES	17.7%	3.2%				
			PUB	7.5%	1.9%	1.7%			
			REC	18.7%	6.1%	2.3%	3.6%		
			PRC	48.4%	15.2%	6.2%	16.6%	29.0%	
			OTH	7.7%	2.1%	1.6%	2.6%	6.9%	0.9%
	H2020	Art. 187	HES	14.5%	1.3%				
			PUB	3.7%	0.4%	0.3%			
			REC	16.8%	2.2%	1.1%	1.8%		
			PRC	62.2%	8.8%	6.2%	18.5%	54.9%	
			OTH	2.9%	0.5%	0.3%	0.5%	3.0%	0.1%
	H2020	cPPP	HES	14.8%	2.0%				
			PUB	2.5%	0.8%	0.4%			
			REC	16.8%	3.7%	1.0%	2.4%		
			PRC	63.2%	17.2%	4.4%	18.9%	42.0%	
			OTH	2.7%	0.8%	0.8%	1.2%	4.0%	0.4%
3.5. “Climate”	Fp7	Except Art. 187	HES	28.9%	10.7%				
			PUB	6.2%	2.4%	2.2%			
			REC	28.5%	17.6%	4.1%	9.7%		
			PRC	33.3%	15.7%	2.4%	14.9%	15.0%	
			OTH	3.1%	1.3%	0.5%	1.5%	1.9%	0.2%
	H2020	Societal challenge except partnerships and SME	HES	22.7%	6.4%				
			PUB	9.6%	4.3%	2.0%			
			REC	25.0%	12.5%	4.8%	7.9%		
			PRC	32.0%	11.3%	5.0%	12.6%	12.3%	
			OTH	10.7%	4.2%	2.9%	5.0%	6.3%	2.5%

Notes:
The group of Fp7 projects was defined by applying keyword queries related to each societal challenge (restricted to projects classified under the “Cooperation” part of that programme and excluding Article 187 projects)
The cPPP group contains projects listed in the websites of 2 specific cPPPs (Green Vehicle - https://www.2zeroemission.eu/projects/; and Energy Efficient Buildings - https://e2b.ectp.org/project-database-list/);
The H2020 SC groups exclude both SME instrument (phase I and II, as these were specific to the private sector.

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)

Societal	Programme	Group	Sector	Share of	Share of collaboration with:

REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

Error! Reference source not found. presents the distribution of participation and EC contributions by organisation types in each societal challenge. The shares were computed in 2 ways. The rows "total of the group across all org types" indicate the participation or EC contributions assigned to each organization type in each group of projects. For example, 61.3% of participation from projects under the Art. 187 in societal challenge 3.2. Food. The share displayed just below this score in **Error! Reference source not found.** indicates that the private participation (PCR) from the Art. 187 corresponded to 29.6% of the total private participation in this societal challenge.

Table 11. Share of participation and EC contributions by sector in H2020 societal challenges.

Societal Challenge	Group	As a share (%) of	Share (%) participation					Share (%) EC contribution				
			HES	PUB	REC	PRC	OTH	HES	PUB	REC	PRC	OTH
3.2. "Food"	All projects in this societal challenge	The total of the group across all org types	23.9	5.4	27.3	32.6	10.7	27.3	2.8	31.0	32.4	6.5
		This same org types in this societal challenge	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Societal challenge except partnerships and SME	The total of the group across all org types	26.3	6.3	29.4	26.5	11.5	33.3	3.8	36.3	19.3	7.3
		This same org types in this societal challenge	91.8	97.7	89.5	67.7	89.4	89.9	98.4	86.3	43.8	81.9
	Art. 187	The total of the group across all org types	12.4	0.8	18.2	61.3	7.2	11.9	0.2	18.2	64.6	5.1
		This same org types in this societal challenge	8.2	2.3	10.5	29.6	10.6	10.1	1.6	13.7	46.3	18.1
EU.3.3. "Energy"	All projects in this societal challenge	The total of the group across all org types	16.3	7.6	18.5	45.6	11.9	16.5	5.3	21.2	49.6	7.4
		This same org types in this societal challenge	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Societal challenge except partnerships and SME	The total of the group across all org types	16.8	8.2	18.6	43.6	12.8	17.8	5.4	22.3	46.4	8.0
		This same org types in this societal challenge	88.0	92.0	85.4	81.5	91.8	90.1	84.7	88.0	78.2	90.5
	Art. 187	The total of the group across all org types	15.7	2.0	24.1	54.7	3.4	9.1	1.3	17.2	70.4	2.0
		This same org types in this societal challenge	6.6	1.8	8.9	8.2	2.0	4.2	1.8	6.2	10.8	2.1
	cPPP	The total of the group across all org types	12.7	6.8	15.3	54.5	10.8	15.6	11.9	20.3	43.1	9.1
		This same org types in this societal challenge	5.4	6.1	5.7	8.3	6.3	5.7	13.5	5.8	5.2	7.4
EU.3.4. "Transport"	All projects in this societal challenge	The total of the group across all org types	15.8	5.2	17.4	56.6	5.0	13.1	3.5	18.6	61.9	3.0
		This same org types in this societal challenge	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Societal challenge except partnerships and SME	The total of the group across all org types	17.7	7.5	18.7	48.4	7.7	19.1	5.3	22.2	48.2	5.2
		This same org types in this societal challenge	49.6	63.4	47.3	37.8	68.8	55.1	57.7	45.1	29.4	65.2
	Art. 187	The total of the group across all org types	14.5	3.7	16.8	62.2	2.9	9.4	2.6	16.2	70.1	1.7
		This same org types in this societal challenge	42.3	32.4	44.3	50.7	26.5	35.7	37.3	43.6	56.5	27.9
	cPPP	The total of the group across all org types	14.8	2.5	16.8	63.2	2.7	12.8	1.9	22.4	60.6	2.2
		This same org types in this societal challenge	8.1	4.2	8.3	9.7	4.7	9.2	5.1	11.4	9.2	6.9
3.5.	All projects in this societal	The total of the group across all org types	22.9	9.5	25.0	32.1	10.6	26.0	7.8	29.5	29.8	6.8

Societal Challenge	Group	As a share (%) of	Share (%) participation					Share (%) EC contribution				
			HES	PUB	REC	PRC	OTH	HES	PUB	REC	PRC	OTH
“Climate”	challenge	This same org types in this societal challenge	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Societal challenge except partnerships and SME	The total of the group across all org types	22.9	9.6	25.2	31.4	10.8	26.7	8.1	30.5	27.6	7.1
		This same org types in this societal challenge	98.4	100.0	99.2	95.9	100.0	98.8	100.0	99.1	88.8	100.0
	Art. 187	The total of the group across all org types	32.1	0.0	20.2	47.6	0.0	22.7	0.0	31.1	46.2	0.0
		This same org types in this societal challenge	1.3	0.0	0.7	1.4	0.0	0.7	0.0	0.9	1.3	0.0
	cPPP	The total of the group across all org types	70.0	0.0	10.0	20.0	0.0	82.0	0.0	9.3	8.7	0.0
		This same org types in this societal challenge	0.3	0.0	0.0	0.1	0.0	0.5	0.0	0.1	0.0	0.0

Notes:
The cPPP group contains projects listed in the websites of 2 specific cPPPs (Green Vehicle - https://www.2zeroemission.eu/projects/; and Energy Efficient Buildings - https://e2b.ectp.org/project-database-list/);
The groups “All projects in this societal challenge” exclude both SME instrument phase I.
HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

1.5. Centrality of countries and participants

Error! Reference source not found. displays the ranking of selected countries by their respective centrality (using betweenness centrality as the indicator of centrality) in the networks formed by H2020 and FP7 participants in projects related to each societal challenge. For example, France was the most central country in the network related to H2020 projects in Societal Challenge 2. Each network relies on the co-participation in projects between each pair of countries. If a given pair of countries in a project was formed by more than 1 pair of organizations, each pair was considered as 1 collaboration. Countries with more participation in each of these networks are more likely to appear in the top ranks in this indicator meaning that this analysis would provide similar results to one based on the number of participations per country.

As expected, countries in the EU-14 group and the United Kingdom are usually the most central countries across all networks (Societal Challenges) with the exceptions of smaller countries such as Luxembourg. France, Germany, Italy, Spain and the United Kingdom held most of the top positions across all societal challenges in Fp7 or H2020. Concerning the network defined for projects in the H2020 societal challenge “Food”, France was the most central country (it was the second in the Fp7), followed by Italy (sixth in the Fp7) and the United Kingdom (first in the Fp7). For Societal Challenge “Energy”, Germany, Spain and France were the 3 most central countries in H2020. In “Transport”, the United Kingdom, Netherlands, and France were the most central countries, while in “Climate”, the 3 most central countries were the United Kingdom, Netherlands, and Italy.

Table 12. Countries by ranking of centrality in the network of participants in H2020 and FP7.

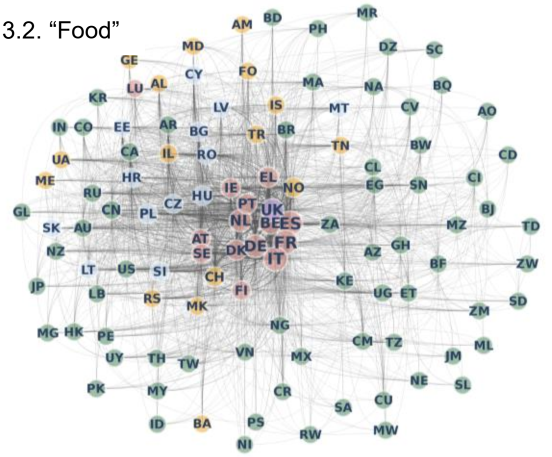
Group / Country	3.2. “Food”		3.3. “Energy”		3.4. “Transport”		3.5. “Climate”	
	Fp7	H2020	Fp7	H2020	Fp7	H2020	Fp7	H2020
EU-14								
Austria	8	18	11	7	11	13	11	8
Belgium	7	6	10	6	3	5	7	7
Denmark	9	9	19	14	12	19	10	9
Finland	19	16	17	11	10	10	19	18
France	2	1	2	3	4	3	3	6
Germany	4	4	1	1	2	6	1	4
Greece	17	12	13	18	9	9	9	14
Ireland	34	14	6	16	18	18	31	17
Italy	6	2	4	4	6	4	6	3
Luxembourg	99	65	45	39	41	35	97	57
Netherlands	3	7	8	5	17	2	4	2
Portugal	14	8	14	13	7	11	17	12

Spain	5	5	5	2	1	8	5	5
Sweden	12	13	25	12	8	7	8	10
United Kingdom	**1**	**3**	**3**	**8**	**5**	**1**	**2**	**1**
EU-13								
Bulgaria	44	26	21	46	29	29	35	26
Croatia	39	36	42	22	43	32	48	30
Cyprus	65	58	33	44	45	24	44	31
Czechia	38	24	27	23	26	22	24	24
Estonia	49	44	59	57	57	30	60	35
Hungary	22	19	41	35	23	21	29	28
Latvia	60	47	36	31	27	25	64	69
Lithuania	36	53	50	21	31	27	70	33
Malta	75	59	9	48	57	37	68	36
Poland	27	20	20	19	24	14	20	19
Romania	43	21	31	17	20	20	39	22
Slovakia	56	61	40	55	42	34	65	40
Slovenia	20	40	35	15	30	26	28	15
H2020-associated (excluding UK)								
Albania	95	74	84	69	N/C	52	75	76
Armenia	118	100	66	87	N/C	N/C	123	95
Bosnia and Herzegovina	102	100	N/C	41	N/C	52	123	60
Switzerland	10	15	15	9	15	12	13	11
Faeroe Islands	93	50	N/C	87	N/C	52	99	78
Georgia	59	85	55	47	N/C	N/C	66	62
Israel	26	25	12	54	13	33	18	25
Iceland	41	38	63	40	57	52	69	38
Liechtenstein	118	N/C	84	N/C	57	N/C	123	N/C
Moldova	118	82	84	N/C	57	N/C	123	71
Montenegro	84	80	84	87	N/C	52	123	95
North Macedonia	85	56	64	50	N/C	36	77	68
Norway	11	10	23	10	16	16	14	13
Serbia	66	31	51	25	32	40	54	32
Tunisia	32	37	32	63	57	N/C	33	29
Turkey	28	28	16	30	14	17	12	21
Ukraine	29	67	39	45	33	41	36	45

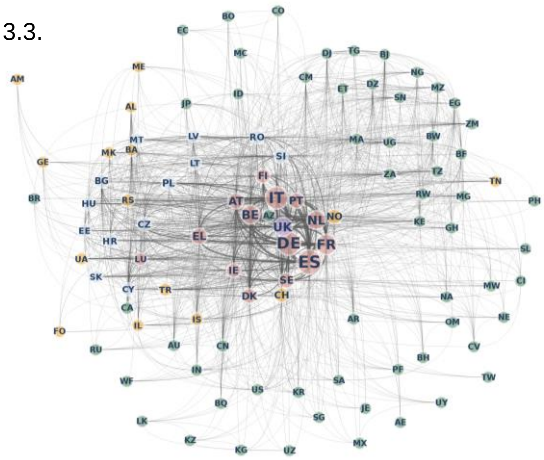
NOTES:
Some rankings are the same for different countries, representing ties in the indicator.
Some scores are presented as N/C (not computed) as the country did not have participation in the given group.
Third countries are not included in this table but were used to compute the networks from which these scores were computed. That is why there are some rankings that have been skipped in this table. The most notable case was South Africa in the network “FP7 - 3.3.”, which ranked 7th.

Figure 19 plotted each of the H2020 networks and shows that, usually, countries from the EU-14 and the United Kingdom tended to populate the centre of each network, reflecting the centrality scores observed in Table 11. Moreover, usually, EU-13 and Associated countries are in more central parts of each plot compared to Third Countries, also expected, given the centrality scores exhibited by countries in these groups.

3.2. “Food”



3.3.



3.4. “Transport”

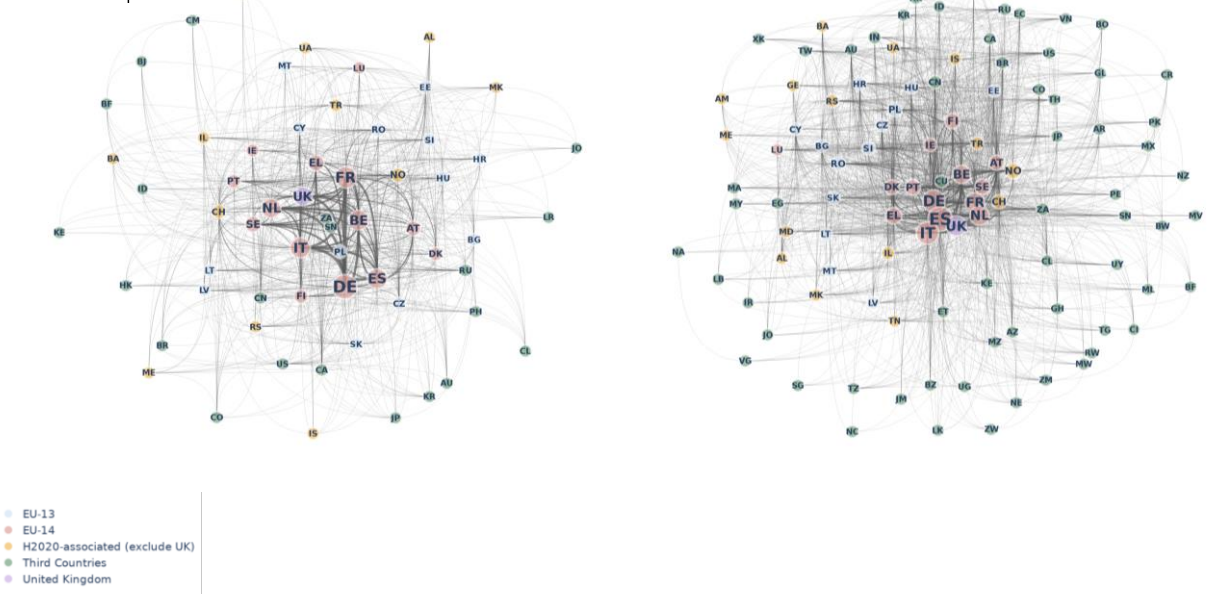


Figure 19. Representation of networks of countries in H2020 societal challenges 2 to 5.

A complementary analysis based on the collaborations between organizations was performed to identify the most central organizations in each H2020 societal challenge. Education (HES) and Research (REC) Organisations were the most central institutions in all societal challenges (with one exception in societal challenge 5). It is worth mentioning that the most central institutions listed in Table 11 were also ranked among those with more participation in project results.

The countries of the organisations presented in Table 15 are not necessarily among the top countries presented in Table 14. In Societal Challenge "Food", two of the top 5 institutions were from the Netherlands, which was only the seventh country in this societal challenge in Table 14. In societal challenge “Energy” one of the most central organisations is from Denmark, listed in the 14th position in Table 14. Two organisations from Greece appeared among the most central ones in societal challenges “Transport” and “Climate”, even though this country is listed in the 9th and 14th positions in these societal challenges in Table 14.

Table 13. Most central institutions in H2020 by Societal Challenge.

Societal Challenge	Organisation Name	Type	Country	Rank by betweenness centrality	Rank by number of participation
3.2. “Food”	Stichting Wageningen Research	REC	Netherlands	1	2
	Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement	REC	France	2	1
	Agencia Estatal Consejo Superior de Investigaciones Cientificas	REC	Spain	3	3
	Wageningen University	HES	Netherlands	4	4
	Consiglio Nazionale delle Ricerche	REC	Italy	5	5
3.3. “Energy”	Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung e.v.	REC	Germany	1	1
	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek tno	REC	Netherlands	2	2
	Fundacion Circe Centro de Investigacion de Recursos y Consumos Energeticos	REC	Spain	3	9
	Fundacion Tecnalia Research & Innovation	REC	Spain	4	5
	Danmarks Tekniske Universitet	HES	Denmark	5	4
3.4. “Transport”	Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung e.v.	REC	Germany	1	2
	Deutsches Zentrum fur Luft - und Raumfahrt ev	REC	Germany	2	1
	Ethniko Kentro Erevnas Kai Technologikis Anaptyxis	REC	Greece	3	4
	Technische Universiteit Delft	HES	Netherlands	4	3
	Nederlandse Organisatie voor toegepast natuurwetenschappelijk onderzoek - TNO	REC	Netherlands	5	5
3.5. “Climate”	National Technical University of Athens - NTUA	HES	Greece	1	5
	Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung e.v.	REC	Germany	2	3
	ECLEI European Secretariat gmbh	OTH	Germany	3	12
	Technische Universiteit Delft	HES	Netherlands	4	10
	Consiglio Nazionale delle Ricerche	REC	Italy	5	3

1.6. New participation in H2020

Error! Reference source not found. shows the share of new participants for each H2020 Societal Challenge and type of organisation. Private, Public and Other organizations are those with the highest shares of new participation (computed over the total participation from the same organization type). Educational and Research establishments exhibited the lowest shares of new participation, possibly reflecting the higher rates of participation in the prior framework programmes of these types of organisations. **Error! Reference source not found.** reports the geographical distribution of new participation by group of countries. The group "Other countries" displayed the highest shares of new participation across all societal challenges and types of organisations. The exception was public organisations in societal challenge 3.3., where the H2020 Associated countries exhibited the highest share of new participation, with 70%.

Table 14. New participation in H2020 by societal challenge

Societal Challenge	HES	PUB	REC	PRC	OTH
3.2. “Food”					
Total participation	2,857	645	3,266	3,896	1,281
New participation	205	317	366	2,423	867
Share of New participation (%)	**7.2**	**49.1**	**11.2**	**62.2**	**67.7**
3.3. “Energy”					
Total participation	2,233	1,042	2,538	6,242	1,627
New participation	113	610	311	3,774	1,207
Share of New participation (%)	**5.1**	**58.5**	**12.3**	**60.5**	**74.2**
3.4. “Transport”					
Total participation	2,314	762	2,557	8,299	727
New participation	103	355	148	3,566	252
Share of New participation (%)	**4.5**	**46.6**	**5.8**	**43.0**	**34.7**
3.5. “Climate”					
Total participation	2,086	863	2,276	2,930	964
New participation	142	440	256	1,829	673
Share of New participation (%)	**6.8**	**51.0**	**11.2**	**62.4**	**69.8**

Notes:
Excludes SME instrument phase I projects.
One participation is defined as the participation of one organisation in one project (i.e., if one organisation is involved in multiple projects, it counts as multiple participation, which is equivalent to the number of projects involving this organisation).
Participation was defined as new when the organisation was not funded under the FP7 programme.

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

Table 15. New participation in H2020 by societal challenge and group of country.

Societal Challenge / Group of country	Indicator	HES	PUB	REC	PRC	OTH
3.2. “Food”						
EU27+UK-H2020	New participation	2,400	503	2,801	3,521	1,172
	Share of New participation	5.0%	51.5%	9.4%	61.2%	65.5%
H2020 Associated	New participation	195	73	262	289	58
	Share of New participation	7.2%	23.3%	12.2%	65.4%	89.7%
Other Countries	New participation	262	69	203	86	51
	Share of New participation	27.5%	59.4%	34.5%	91.9%	92.2%
3.3. “Energy”						
EU27+UK-H2020	New participation	1,892	954	2,314	5,740	1,538
	Share of New participation	3.2%	58.0%	12.1%	59.7%	73.3%
H2020 Associated	New participation	223	58	194	435	68
	Share of New participation	6.3%	70.7%	9.8%	66.0%	88.2%
Other Countries	New participation	118	30	30	67	21
	Share of New participation	33.1%	53.3%	40.0%	92.5%	90.5%
3.4. “Transport”						

EU27+UK-H2020	New participation	2,145	704	2,391	7,795	685
	Share of New participation	3.6%	45.6%	5.6%	41.9%	32.1%
H2020 Associated	New participation	114	39	123	422	34
	Share of New participation	4.4%	51.3%	4.1%	57.6%	73.5%
Other Countries	New participation	55	19	43	82	8
	Share of New participation	36.4%	73.7%	18.6%	65.9%	87.5%
3.5. "Climate"						
EU27+UK-H2020	New participation	1,683	725	1,958	2,677	855
	Share of New participation	4.1%	51.6%	9.4%	61.0%	66.8%
H2020 Associated	New participation	196	76	196	166	47
	Share of New participation	9.7%	35.5%	14.8%	69.9%	89.4%
Other Countries	New participation	207	62	122	87	62
	Share of New participation	26.1%	62.9%	35.2%	93.1%	96.8%

Figure 20 shows that the share of participation of newcomers had increased during the H2020 period in the 4 societal challenges. Except for Energy, where the increase was mostly gradual each year, for the remaining societal challenges, the increase was more accentuated in 2015, compared with 2014, followed by periods of some fluctuation in the shares of newcomers. Important to remark that newcomers were defined solely based on prior participation in the FP7 programme, meaning that, an organization that did not participate in FP7 grants, was considered a newcomer in all H2020 projects, regardless of prior participation of this organization in prior years in the H2020 programme (e.g., an organisation that did not participate in FP7, was considered as a H2020 newcomer in a project starting in 2020, even if this same organization had participated in a prior H2020 project starting in 2015, for example).

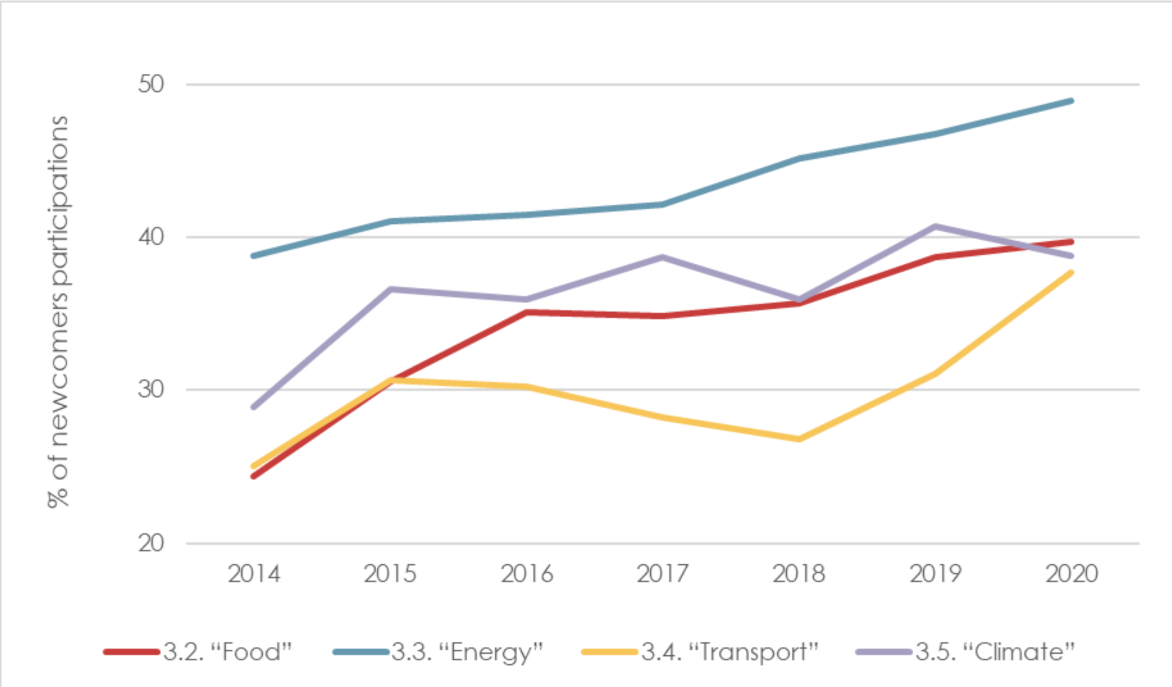


Figure 20. Share of newcomer organizations by societal challenge and year of call.

1.7. SME participation

Error! Reference source not found. shows that the share of projects with at least 1 SME participant was 84.6% when the 4 societal challenges were considered together. Transport exhibited the lowest share, with 75% of its projects having at least 1 SME participant. Food was the societal challenge with the highest share of projects involving SMEs, with 93%. As expected, all projects under the SME-II instrument involved SME participation. Considering only CSA, IA, and RIA projects, the share of projects involving SMEs was lower for CSA actions (79.3%) and higher for IA (84%).

Table 16. Share (%) of H2020 Green-transition projects with at least 1 SME participant by societal challenge 2 to 5.

Instrument-Action	3.2. "Food"	3.3. "Energy"	3.4. "Transport"	3.5. "Climate"	Societal challenges 3.2 to 3.5
All Instruments	93.2	88.9	75.0	90.1	84.6
CSA	81.0	82.3	76.9	62.6	79.3
IA	97.0	96.5	68.5	100.0	84.0
RIA	94.2	88.3	75.2	91.8	83.9
SME-II	100.0	100.0	100.0	100.0	100.0

1.8. Proposals by eligibility status, quality, success rate, and average time to grant

The success rate (defined as the share of eligible proposals that were retained to receive grants) ranged from 13.6% in Energy to 23.7% in transport (**Error! Reference source not found.**). The SME instrument phase II displayed the lowest success rates in the 4 societal challenges (compared to CSA, IA, and RIA) with an average of 6.2% in the 4 societal challenges. For this instrument, the oversubscription rate (computed as the number of high-quality proposals that were not funded divided by the number of retained proposals) reached 620, meaning that 6 high-quality proposals were not granted for each retained proposal on the SME-II instrument. The highest success rate was observed in the SC "Transport", with 23.7% of the proposals retained. The higher success rates in Transport were observed practically across the 4 types of actions considered (except for CSA, with 29%, just slightly below the success rate of CSA-Climate, with 29.7%). The oversubscription rate observed for transport was, then, lower than for the other societal challenges, with 1.57 non-granted proposals for each granted one. Overall, the proposals among the 4 societal challenges exhibited a higher success rate than the average of the H2020 programme (16.9% for the 4 societal challenges vs. 12.6% for H2020) and lower oversubscription rates (217 for the societal challenges vs. 355 for H2020). Time to grant (TTG), displayed in the last column of **Error! Reference source not found.**, showed that the number of days between the closure date of calls until the signature of the contract was not too different across the 4 societal challenges, ranging from 221 days for Transport to 229 for Climate. When the 4 societal challenges are considered together, the average time to grant was 225 days – thus well below the time-to-grant limit of 8 months (~243 days) set out in the legal base - 13 days more than the average of the H2020 programme.

Table 17. Success rate of H2020 proposals by societal challenge 2 to 5.

Societal Challenge / Instrument-Action	Number of proposals				Success Rate (%)	Oversubscription Rate	TTG (days)
	Total	Eligible	High Quality	Retained			
3.2. "Food"							
All Instruments	**6,630**	**4,457**	**2,559**	**665**	**14.9**	**284.8**	**227.3**
CSA	635	593	347	123	20.7	182.1	230.0
IA	1,272	1,176	646	156	13.3	314.1	241.8
RIA	3,396	1,385	983	303	21.9	224.4	241.3
SME-II	1,327	1,303	583	83	6.4	602.4	140.5
3.3. "Energy"							
All Instruments	**8,565**	**7,392**	**3,166**	**1,003**	**13.6**	**215.7**	**227.2**
CSA	1,870	1,813	708	358	19.7	97.8	229.8
IA	1,799	1,700	622	226	13.3	175.2	243.9
RIA	3,199	2,214	1,035	323	14.6	220.4	230.7
SME-II	1,690	1,661	798	94	5.7	748.9	152.9
3.4. "Transport"							
All Instruments	**8,102**	**6,232**	**3,814**	**1,479**	**23.7**	**157.9**	**221.2**
CSA	334	310	176	90	29.0	95.6	212.9
IA	2,046	1,735	1,194	562	32.4	112.5	237.4
RIA	4,178	2,680	1,822	709	26.5	157.0	223.8
SME-II	1,541	1,505	620	117	7.8	429.9	144.7
3.5. "Climate"							
All Instruments	**5,983**	**3,636**	**2,075**	**516**	**14.2**	**302.1**	**229.7**
CSA	329	303	187	90	29.7	107.8	228.7

IA	2,100	886	521	153	17.3	240.5	238.1
RIA	2,278	1,189	811	211	17.7	284.4	244.9
SME-II	1,274	1,257	555	61	4.9	809.8	154.2
Societal challenges 3.2 to 3.5							
All Instruments	**28,922**	**21,559**	**11,52**	**3,635**	**16.9**	**216.9**	**225.2**
CSA	3,126	2,979	1,395	653	21.9	113.6	227.4
IA	7,198	5,484	2,978	1,094	19.9	172.2	239.7
RIA	12,754	7,363	4,586	1,529	20.8	199.9	231.5
SME-II	5,832	5,726	2,556	355	6.2	620.0	147.5
H2020 programme							
All Instruments	**256,269**	**237,307**	**135,614**	**29,796**	**12.6**	**355.1**	**212.6**
CSA	11,859	10,986	6,388	2,599	23.7	145.8	214.8
IA	19,596	16,375	6,916	2,274	13.9	204.1	228.9
RIA	46,031	33,841	17,751	4,529	13.4	291.9	230.1
SME-II	40,795	40,248	15,635	1,510	3.8	935.4	151.7

1.9. Additional project outputs (except peer reviewed publications and patents)

Error! Reference source not found. presents the count of outputs reported in the eCorda database for H2020 projects in each societal challenge. Differently from scientific papers and patents, only the number of projects reporting each output type, number of outputs, and number of outputs per reporting project are presented below. The number of utility models, registered designs and trademarks reported in eCorda for these societal challenges is very low, with only a small share of the total projects reporting at least 1 output in these categories. For demonstrator/pilot prototype and open research data, the number of outputs per reporting project is very similar across the 4 societal challenges in each of these outputs. For the aggregate of the societal challenges, on average, each reporting project reported 3 demonstrators/pilot prototypes and 1.2 open research data. Unfortunately, the lack of comparators in similar research domains and the absence of any measurement of the impact or quality of these outputs prevent further analysis of these outputs.

Table 18. Outputs reported by H2020 projects (excludes peer reviewed publications and patents).

Societal Challenge	Nb total projects	Utility models			Registered Design			Trademarks		
		Nb reporting projects	Nb Outputs	Outputs per reporting project	Nb reporting projects	Nb Outputs	Outputs per reporting project	Nb reporting projects	Nb Outputs	Outputs per reporting project
SC 3.2: "Food"	687	4	6	1.5	3	3	1.0	16	22	1.4
SC 3.3: "Energy"	1,110	3	4	1.3	6	8	1.3	11	17	1.5
SC 3.4: "Transport"	1,434	0	0		3	4	1.3	19	29	1.5
SC 3.5: "Climate"	524	0	0		0	0		10	21	2.1
Total (deduplicated)	3,727	7	10	1.4	12	15	1.3	56	89	1.6

Societal Challenge	Nb total projects	Demonstrator/Pilot prototype			Open Research data		
		Nb reporting projects	Nb Outputs	Outputs per reporting project	Nb reporting projects	Nb Outputs	Outputs per reporting project
SC 3.2: "Food"	687	95	261	2.7	97	115	1.2
SC 3.3: "Energy"	1,110	168	546	3.3	141	176	1.2
SC 3.4: "Transport"	1,434	165	495	3.0	248	277	1.1
SC 3.5: "Climate"	524	103	279	2.7	149	201	1.3
Total (deduplicated)	3,727	525	1,560	3.0	628	762	1.2

1.10. Partnership data

The Annex VII of the Tender Specification of this project listed the partnerships covered under this study. It included the following partnerships:

- Art. 185: PRIMA
- Art. 187: Bio-based Industries (BBI); CleanSky 2; Fuel Cells and Hydrogen (FCH 2); Single European Sky ATM Research (SESAR) Joint Undertaking; Shift2Rail
- EIT KIC: Urban mobility; Climate; Food; InnoEnergy

- cPPP: European Green Vehicle Initiative; Energy efficient buildings

- ERANET Cofund / EJP Cofund / Joint Programming Initiatives: 46 partnerships under these categories.

The eCorda database did not provide comprehensive coverage of all these partnerships. For instance, eCorda was used as the source of data only for the partnerships under Article 187 and cPPP. While eCorda contains clear identifiers to select the Article 187 partnerships unequivocally, the identification of the grants related to the 2 cPPPs partnerships required the matching of grant acronyms to external lists of cPPPs grants directly extracted from these partnerships' websites (https://www.2zeroemission.eu/projects/ and https://e2b.ectp.org/project-database-list/). Some grant acronyms extracted from these websites were initially matched to multiple grants in eCorda. For these cases, the data was curated to find the right unique match, by using complementary information such as dates of projects and also looking at the projects' descriptions in some cases. While this procedure allowed the precise identification of cPPP grants in eCorda, if, for any reason, a cPPP grant was not listed on these websites, we could not correctly classify them as cPPPs, meaning that, if this happened, they remained classified as non-partnership projects. Also, it is important to highlight that this procedure was specifically employed to identify those 2 cPPPs listed in Annex VII of the Tender, meaning that if any other cPPP grant were linked to Societal Challenges, they were not captured.

For the remaining partnerships, different data sources were used. For the EIT-KICs, a series of Excel files were provided by the European Commission (1 for each EIT per year). Data from ERA-LEARN was used for the PRIMA, ERANET Cofund, EJP Cofund, and Joint Programming Initiatives. Even though a considerable amount of time has been invested to interpret these additional sources and to curate the data, it should be acknowledged that the data regarding these partnerships did not permit the same level of analysis as provided in the main tables above. These extra tables on partnerships are provided, then, in this section to reference analyses of partnerships that were provided in different parts of this report.

Error! Reference source not found. summarises the data related to the P2P networks. The data provided by ERA-LEARN was summarized at the level of types of networks and societal challenges, using the links between P2P projects and societal challenges available in the raw tables. The ERA-NET COFUND accounted for most of the networks included in this project, with 38 networks grouping 798 projects. Climate and Food accounted for most of these projects (388 and 289 projects respectively), followed by Energy (173) and Transport (83). ERA-NET COFUND was the only type of network with enough data to produce indicators based on the EC contributions to these projects. The average EC contribution per project in these networks was EUR 297,505 (ranging from EUR 175,661 for Food projects to EUR 487,236 for Energy projects). These figures differ substantially from the average EC contribution per project on the non-partnership H2020 projects reported in the main text (EUR 4.9 million). Also, it is worth noting that the average EC contribution as a share of the total cost per project in the P2P projects (17%) is much lower than the share of EC participation in the remaining projects reported in the main text (86%). The ERA-NET Cofund projects, typically, involved 7.3 participants per project (ranging from 6.6 in Food to 9.0 in Transport), from 4.5 countries, on average (ranging from 3.6 countries in Transport to 5.0 in Energy).

The data provided by ERA-Learn did now allow us to compute the same proposal-based indicators provided in the main text for the remaining projects (High-quality, oversubscription rate, time-to-grant). The basic analysis at proposal level for P2P data regards the share of proposals that have been approved and granted. This share ranged from 6% (PRIMA) to 14% (ERA-NET Cofund), with some variation in each Societal Challenge, with the highest share of proposals granted observed among the Energy-related networks of the ERA-NET Cofund.

Table 19. P2P partnerships, number of projects, networks, proposals, participation, and investments.

Network Type	Societal Challenge	Number of networks included	Number of proposals	Number of projects funded	Budget (EUR million)		Actual investment (EUR million)		EC Budget per project (EUR 1,00)	Total Budget per project (EUR 1,00)	N of participation per project	N of countries per project	Projects with data on participants
					EC	Total	EC	Total					
185	**2 - Food and 5 - Climate***	1	2,119	129	N/C						9.3	5.7	129
EJP Cofund	5 - Climate	1	0	10	N/C						N/A		0
JPI	**Any**	6	826	91	9.3	152.3	0.0	84.9	N/C	1,673,378	7.0	4.8	65
	2 - Food	2	176	33	N/C						7.2	5.2	18
	3 - Energy	1	128	11							5.7	3.2	11
	5 - Climate	5	826	81	N/A	124.1	N/A	84.9	N/A	N/A	7.0	4.8	65
ERA-NET Cofund	**Any**	38	5,552	798	237.4	1,410.8	178.4	944.5	297,505	1,767,866	7.3	4.5	714
	2 - Food	12	2,188	289	50.8	380.6	35.5	252.5	175,661	1,316,989	6.6	4.4	258
	3 - Energy	10	745	173	84.3	463.1	51.1	260.7	487,236	2,676,855	8.9	5.0	123
	4 - Transport	4	599	83	26.8	158.4	21.0	114.2	322,696	1,908,983	9.0	3.6	83
	5 - Climate	19	3,101	388	123.0	632.1	104.8	477.7	317,135	1,629,071	6.9	4.8	358

NOTES:
* All grants from PRIMA partnerships were simultaneously linked with the societal challenges Food and Climate.
The terminology Network was used to align with the terminology used by ERA-LEARN. Examples of Networks are: (EJP Soil, OneHealthEJP, FACCE JPI, JPI Climate, and PRIMA).
N/C: ERA-LEARN requested that the financial data was not displayed at the level of individual networks. Therefore, when the number of networks was too low (less than 3), the financial data was reported as N/C.
N/A: Data not available in the source tables.
For the JPI Energy call, 0 proposals were reported (associated with 10 funded projects).
Number of participants per project and number of countries per project is based on a smaller set of projects (column Projects with data on participants) for which the information related to participants, including their countries, was available.

Table 22 provides the summary of the data that was provided by the European Commission on the 4 EIT KICs under the scope of this evaluation. Important to notice that different to the data related to the other partnerships and the non-partnership grants, KICs are not organized under grants or projects. Instead, KICs are organized by KAVA (KIC Added Value Activities) which was used as the basis for computing the data below. Some of these activities were in place across multiple years, and, therefore, the column "Nb of KAVA–new" reports the number of activities starting in that given year. The total number of activities per year refers to the sum of new activities in each year of the period, except for the first year, in which all activities were used. This same method was used to compute the number of new participants in KAVA for the periods. The KCAs are complementary activities to KAVA that were not funded by the EITs. The funding for these complementary activities was, therefore, provided in different columns. Finally, note that different from the other tables, there is no societal challenge intersecting the data provided for each KIC, as this information was not available in the raw tables received for this partnership. In any case, each KIC can be directly associated with one societal challenge based solely on their names.

The funding amounts (from all sources) per KAVA activity are considerably lower than the funding (all sources) per project of the non-partnership projects displayed in **Error! Reference source not found.Error! Reference source not found.**. Even though the comparison between KIC activities and the typical projects is displayed in **Error! Reference source not found.**, the exercise is reported here to illustrate that KAVA is possibly smaller in scope or oriented towards activities that are typically less costly than those typically associated with the projects reported in previous tables. The funding per activity of Climate KIC was EUR 1.8 million over the period, while the total funding per project was EUR 6.3 million for the societal challenge on climate. Similarly, the funding per KAVA activity was EUR 700 thousand in the Food KIC vs. EUR 6.0 million in the main H2020 projects in the corresponding societal challenge. Finally, the InnoEnergy KIC achieved EUR 1,5 million per KAVA activity, while the average cost of a project in the H2020 Energy societal challenge was EUR 6.6 million.

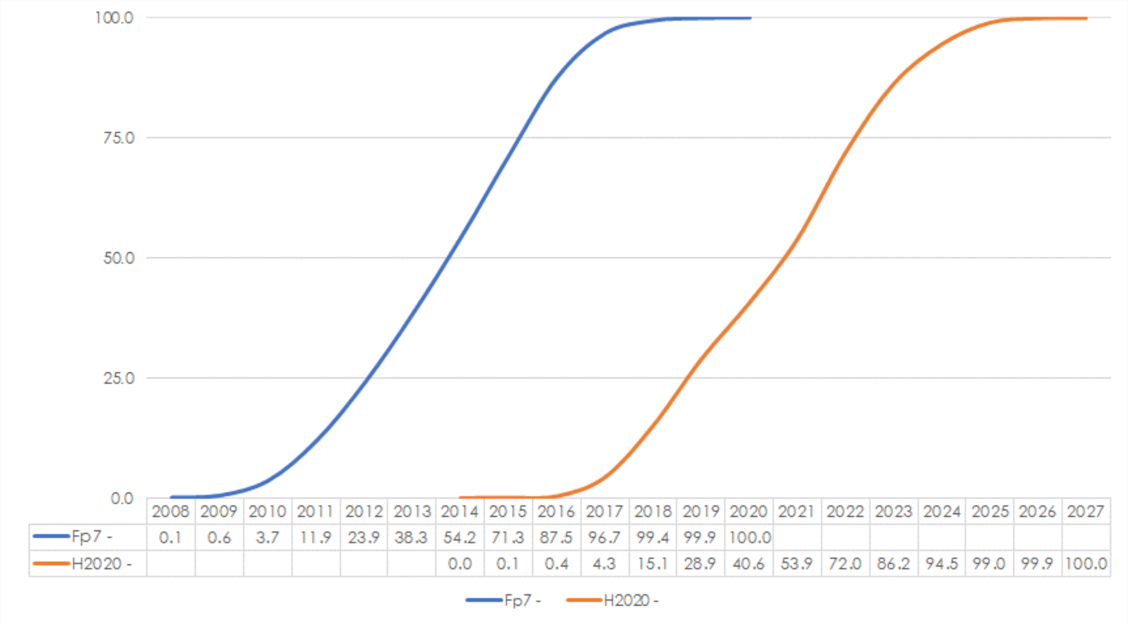
Table 20. EIT KICs partnerships: number of KAVA activities, complementary activities, partners, and funding.

KIC	Period/ Year	Nb of KAVA		Nb of KCA	Nb Participation in KAVA		Funding for KAVA (EUR million)						Funding for KCA (EUR million)			
		Total	New		Total	New	EIT	Partners	Others	All	per activity	per participation	Partners	Others	All	per activity
Climate	**2014-20**	**360**			**2,105**		**559.9**	**102.2**	**6.4**	**668.5**	**1.86**	**0.32**	**1,242.5**	**501.3**	**1,743.7**	
	2020	139	88	44	724	410	93.4	23.3	0.8	117.5	0.85	0.16	97.3	51.9	149.2	3.4
	2019	149	72	60	1059	312	86.2	25.2	3.1	114.5	0.77	0.11	183.0	81.5	264.6	4.4
	2018	136	60	63	1114	289	81.0	23.0	1.4	105.5	0.78	0.09	183.6	127.2	310.8	4.9
	2017	65	8	34	992	40	70.6	12.4	0.4	83.5	1.28	0.08	217.7	62.0	279.7	8.2
	2016	34	4	27	766	32	70.3	8.0	0.5	78.8	2.32	0.10	133.8	63.0	196.8	7.3
	2015	99	16	55	755	108	87.2	2.7	0.1	90.0	0.91	0.12	205.0	53.3	258.3	4.7
	2014	112	82	60	914	561	71.1	7.5	0.1	78.7	0.70	0.09	222.0	62.3	284.3	4.7
Food	**2018-20**	**229**			**1,028**		**129.1**	**31.0**	**0.2**	**160.3**	**0.70**	**0.16**	**235.0**	**49.1**	**284.0**	
	2020	149	90	102	753	404	67.3	12.0	0.1	79.4	0.53	0.11	99.7	16.4	116.2	1.1
	2019	110	68	79	536	329	40.0	9.0	0.0	49.0	0.45	0.09	79.2	20.7	99.8	1.3
	2018	71	71	48	295	N/A	21.8	10.1	0.0	31.9	0.45	0.11	56.1	12.0	68.1	1.4
InnoEnergy	**2014-20**	**415**			**937**		**531.0**	**72.0**	**23.9**	**627.0**	**1.51**	**0.67**	**931.3**	**579.8**	**1,511.1**	**415**
	2020	87	13	25	275	50	89.6	22.1	7.3	119.0	1.37	0.43	116.8	18.9	135.8	5.4
	2019	97	20	19	339	51	90.4	15.5	3.1	108.9	1.12	0.32	52.4	8.9	61.3	3.2
	2018	109	33	35	371	66	80.8	6.9	2.8	90.5	0.83	0.24	103.7	30.8	134.6	3.8
	2017	104	12	49	419	26	75.9	6.5	2.3	84.7	0.81	0.20	76.7	309.2	385.9	7.9
	2016	29	29	17	365	365	71.6	9.9	2.7	84.1	2.90	0.23	184.9	42.9	227.8	13.4
	2015	157	64	95	532	181	68.0	6.6	3.2	77.8	0.50	0.15	162.1	92.2	254.3	2.7
	2014	244	110	143	694	198	54.8	4.5	2.6	61.9	0.25	0.09	234.7	76.8	311.5	2.2
Urban Mobility	2020	85	85	42	414		27.6	5.5	0.0	33.1	0.39	0.08	50.3	37.0	87.3	2.1

NOTES:
KAVA: KIC Added Value Activities; KCA: KIC Complementary Activities
Nb of KAVA and participation in KACA for a group of years was computed as the first number of the series + the sum of new KAVAs or new participation in the following years to avoid double counting. For example, there are 360 KAVAs between 2014 and 2020, which correspond to 112 KAVAs found in the database for the year 2014 plus the new KAVAs found between 2015 and 2020. This same procedure could not be applied to count unique KCAs, because there were no markers for new KCAs in the database. Therefore, counts of KCAs across multiple years are not provided.

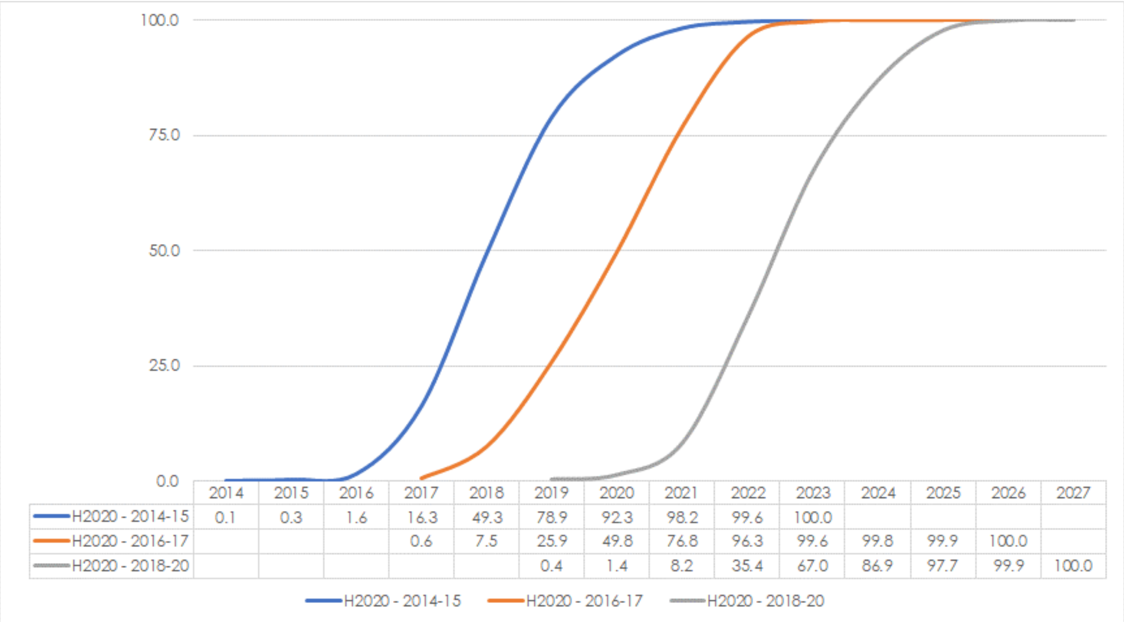
1.11. Timeline considerations for effectiveness analyses

Section 1.2 presented the evolution of H2020 projects over time and indicated that a relevant portion of the projects are yet to be closed. **Figure 21** and **Figure 22** show the distribution of projects in the selected societal challenges by the end year of each project. **Figure 21** compares the distributions for FP7 and H2020 projects, showing similar patterns for both curves and that, by the end of 2021, there were only around 54% of all H2020 projects that were already closed. **Figure 22** shows that, as expected, most of the projects from work programme 2018-2020 have not yet been completed (less than 10% by the end of 2021, the cut-off point for the collection of outputs in this study).



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Fp7 -	0.1	0.6	3.7	11.9	23.9	38.3	54.2	71.3	87.5	96.7	99.4	99.9	100.0							
H2020 -							0.0	0.1	0.4	4.3	15.1	28.9	40.6	53.9	72.0	86.2	94.5	99.0	99.9	100.0

Figure 21. H2020 and FP7: Percentage share of projects closed by year the 4 selected societal challenges.



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
H2020 - 2014-15	0.1	0.3	1.6	16.3	49.3	78.9	92.3	98.2	99.6	100.0				
H2020 - 2016-17				0.6	7.5	25.9	49.8	76.8	96.3	99.6	99.8	99.9	100.0	
H2020 - 2018-20						0.4	1.4	8.2	35.4	67.0	86.9	97.7	99.9	100.0

Figure 22. H2020: Percentage share of projects closed by year and work programme in the 4 selected societal challenges.

As a result, and because research papers can be published even after the closing year of research grants (and it can be considered that most journal publications are issued two or three years after the start date of supporting funding awards), it is expected that a considerable number of H2020 funded papers will be published in the following years, as indicated in **Figure 23.** This figure suggests that most of the papers related to work programme 2014-15 and, to a lesser extent, to work programme 2016-17 have already been published. However, most of the papers from the latest work programme are expected to be published in the following years. This pattern is also reflected in **Error! Reference source not found.**, which shows that the share of H2020 projects with at least one paper published until 2021 is higher for the first two work programmes, compared to the work programme 2018-20. The shares observed for the final work programme are around half of the shares observed in the prior ones for all societal challenges. These observations indicate that the bibliometric results presented in the next section should be considered provisional or most representative of the achievements of projects funded under the work programmes 2014-15 and 2016-17.

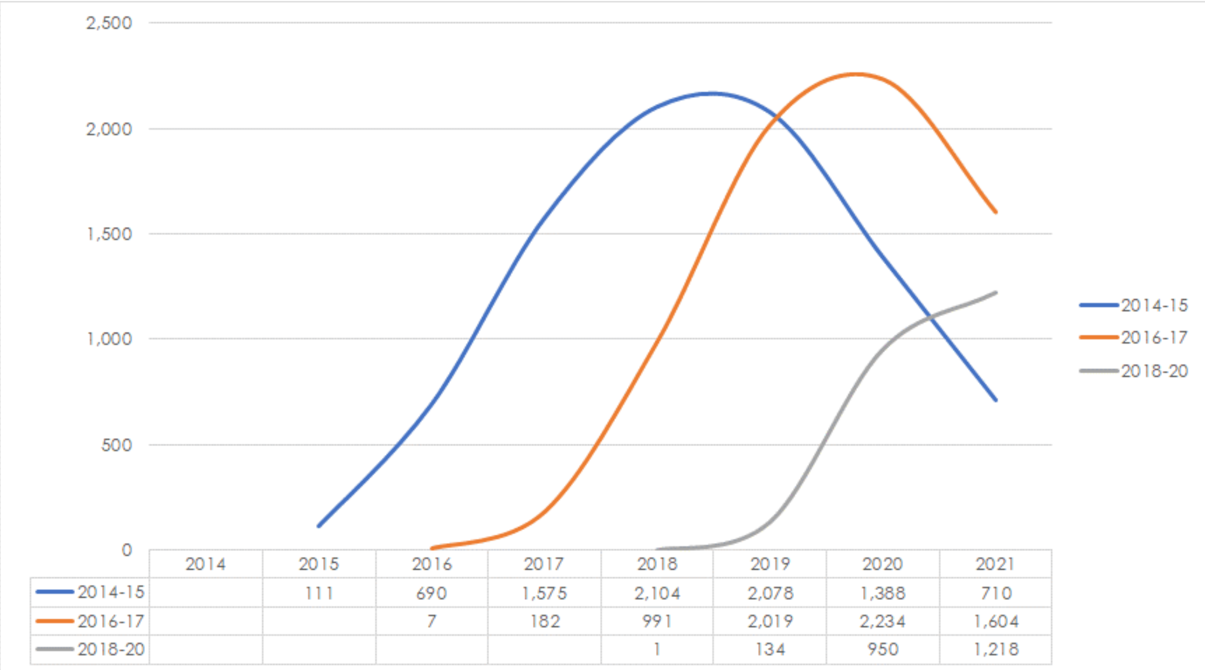


Figure 23. Counts of H2020-supported journal publications (in the four green transition societal challenges) by work programme and year of publication.

Table 21. Percentage share of H2020 projects with at least one paper published until 2021 (inclusively).

Societal Challenge	Work Programme	Share (%) of projects with papers published until 2021
3.2.	2014-15	66
3.2.	2016-17	69
3.2.	2018-20	34
3.3.	2014-15	65
3.3.	2016-17	63
3.3.	2018-20	32
3.4.	2014-15	57
3.4.	2016-17	50
3.4.	2018-20	27
Societal Challenge	**Work Programme**	**Share (%) of projects with papers published until 2021**
3.5.	2014-15	74
3.5.	2016-17	66
3.5.	2018-20	35

2. Technometric analysis

Patenting activity from H2020-funded projects can be expected to provide crucial (if proxy) signals into some of the innovation attainments supported by the framework programme.

Nevertheless, it is most likely too premature as of 2022 to formally assess the patenting activity of H2020-funded projects. The time lag between the launch of fundamental research projects and patenting outcomes is commonly held to range from at the very least six to ten years.[21] This time lag between R&D and patenting may be considerably reduced where a project is specifically oriented towards applied research and technology development,[22] although even there it should be considered that projects require some minimal amount of preparation time before basic working relationships and practices have been set up and can be expected to produce outputs.

Supporting the contention that many patent applications may be effected rather late in FP-funded projects' life cycles, FP7 projects were assigned to SC-equivalent thematic areas based on keyword thematic queries of their abstract, titles and keywords. This method resulted in close to 1,500 FP7 projects with assignations in multiple SC-equivalent thematic areas. By contrast, the H2020 SC-level assignation was based on call information and was mutually exclusive.

Source: eCorda and PATSTAT implementation by Science-Metrix

below shows that 54% of patent applications from FP7-supported projects were made after the closing of FP7 calls (between 2014 and 2021). The patenting findings for SC2- to SC5- funded projects reported below therefore should not be used as evidence in formal evaluation exercises. Moreover, it should be noted that H2020 and FP7 patenting activities are not fully comparable, given discrepancies between the two groups in assigning projects to SC-level groupings. While SC assignation for H2020 projects is straightforward based on the funding call relationship, equivalent relationships were not available for FP7 projects. FP7 projects were assigned to SC-aligned thematic groupings using keyword queries in project descriptions. This method resulted in slightly less than half of FP7 projects contributing to more than one SC-level grouping. That is to say, the same projects and the same patent families contribute to multiple SCs in the table for the FP7 analysis, which is not the case in the H2020 analysis.

[21] Ahmadpoor, M., & Jones, B. F. (2017). The dual frontier: Patented inventions and prior scientific advance. *Science*, *357*(6351), pp. 583–587. doi:10.1126/SCIENCE.AAM9527/SUPPL_FILE/AAM9527_AHMADPOOR_SM.PDF; Langfeldt, L., & Scordato, L. (2015). *Assessing the broader impacts of research. A review of methods and practices*. Oslo: Nordic Institute for Studies in Innovation, Research and Education. Retrieved from https://nifu.brage.unit.no/nifu-xmlui/handle/11250/282742; Popp, D. (2016). Economic analysis of scientific publications and implications for energy research and development. *Nature Energy 2016 1:4*, *1*(4), pp. 1–8. doi:10.1038/nenergy.2016.20.
[22] de Rassenfosse, G., & van Pottelsberghe de la Potterie, B. (2009). A policy insight into the R&D–patent relationship. *Research Policy*, *38*(5), pp. 779–792. doi:10.1016/J.RESPOL.2008.12.013.

Table 22. Patenting output reported by H2020 projects, in comparison to FP7 projects (2007-2021).

	Count of funded projects (all periods)	Patent families count, programme period (2007-2013 for FP7; 2014-2021 for H2020)	Patent families count, post programme (2014-2021 for FP7; 2022-2029 for H2020)
SC2: "Food security"			
H2020	687	59	n/a
FP7 (projects with SC2 equivalent thematic alignment)	868	115	153
SC3: "Energy"			
H2020	1,110	96	n/a
FP7 (projects with SC3 equivalent thematic alignment)	1,391	240	238
SC4: "Transport"			
H2020	1,434	101	n/a
FP7 (projects with SC4 equivalent thematic alignment)	802	65	96
SC5: "Cimate action"			
H2020	524	58	n/a
FP7 (projects with SC5 equivalent thematic alignment)	1,557	171	252
SC2 to SC5 overall			
H2020	3,727	306	n/a
FP7 (projects with equivalent thematic alignment)	3,137	400	465

Note: FP7 projects were assigned to SC-equivalent thematic areas based on keyword thematic queries of their abstract, titles and keywords. This method resulted in close to 1,500 FP7 projects with assignations in multiple SC-equivalent thematic areas. By contrast, the H2020 SC-level assignation was based on call information and was mutually exclusive.

Source: eCorda and PATSTAT implementation by Science-Metrix

3. Bibliometric analysis

3.1. Brief reminder about the bibliometrics approach

This presentation of initial findings of the effectiveness of H2020 in supporting its funded green transition research in achieving several research achievements of interest focuses on results from the counterfactual analysis using a difference-in-differences (DiD) design. The DiD design helps tease out the specific achievements enabled by H2020 funding, apart from the achievements that would have been realized otherwise by supported researchers using other sources of funding. The design approach also helps control secular trends affecting large sections of the research community, for example, yearly incremental gains occurring on the dimension of open-access publishing or international co-publication.

To help control for potential differences in distributions of author-level variables such as seniority, gender, practices linked to different research fronts within subfields and the like, the counterfactual exercise used a comparison group for H2020 papers made up of publications from the same authors as those found on H2020 papers. A further filter was applied to exclude some authors that might appear as coauthors on H2020 but are not direct participants in H2020 projects themselves: only authors with at least two H2020-funded publications were kept in the list used to assemble the list of parallel publications. The list of parallel publications is used as a baseline comparator for H2020 publications, although using publications from the 2014 period rather than from a prior period.

3.2. Key findings on differential achievements enabled by H2020 support

H2020 green transition led to differential increases in achievements, versus other sources of funding, on the following dimension:

- Research excellence as defined by shares of publications falling with the most highly cited or exceptionally highly cited subsets of their respective subfields (all SCs)
- Research excellence as defined by citation impact profiles across all publications (independently of the effects of highly cited outlier publications – all SCs)
- Shares of journal publications available in OA (all SCs)
- Shares of journal publications with uptake in the policy-related literature (for SC3.2, findings for others statistically inconclusive)
- Shares of journal publications cited in patents (for SC3.2, albeit with a major temporal limitation to this analysis)
- Shares of journal publications with active dissemination or attention on Facebook and Twitter (SCs 3.2 and SC3.3)

The figure below illustrates the workings of the counterfactual analysis of H2020 support for green transition research projects, on the dimension of the citation distribution index (CDI). The CDI is a citation impact indicator that offers a synthetic overview of citation impact performances that is not skewed by the sometimes strong effects of citation outliers on citation averages. The world-level (paper-level average in large-scale aggregates of subfield, years and document types) reference value is 0 on this indicator.

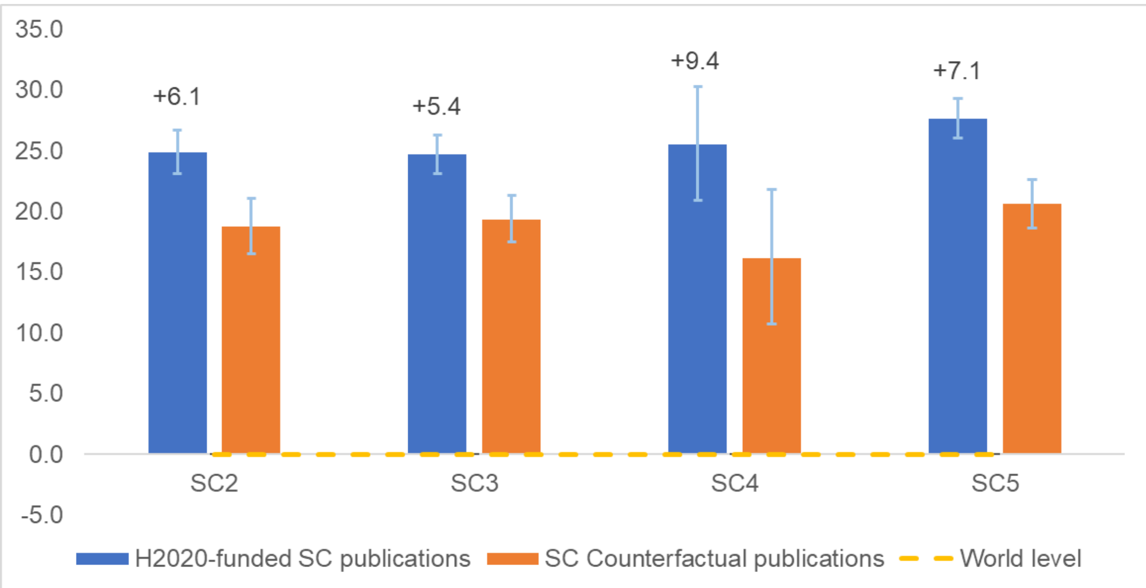


Figure 24. Differential increases in citation distribution index scores, by Societal Challenge and respective baseline comparator (2014-2021).

Source: Scopus implementation by Science-Metrix

For all SCs, H2020 funding has led to large differential increases in citation impact for 2014-2021 publications, considered against the baseline of parallel publications by the same H2020- (directly or indirectly) supported researchers. These differential increases range between +5 (SC3.3) points to + 9 points (SC3.4), although please note that differences between publications by SCs are not statistically definitive. H2020 support has enabled European and other supported researchers to reach top-tier status within the subset of their H2020-funded publications (Science-Metrix considers a CDI of 25 to be the threshold of strong citation impact profiles in most settings, although this is a rough indication rather than a definitive rule. Determining the threshold of CDI capturing world-leading performances requires specific investigation adapted to different subfields and contexts).

The figure below also presents H2020 against parallel publications by SC, this time capturing differential gains in OA publishing. These gains range from + 12 percentage points for SC3.4 and SC3.5 to + 12 percentage points in SC3.3.

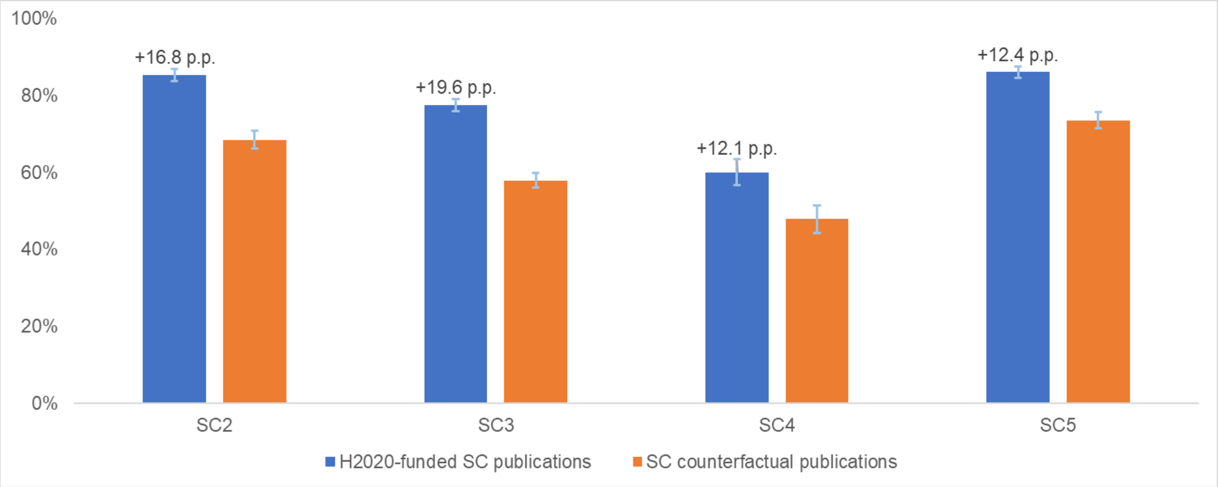


Figure 25. Differential increases in shares of publications available under an open access modality, by Societal Challenge and respective baseline comparator (2014-2021).

Source: Scopus implementation by Science-Metrix; Unpaywall

However, on many dimensions, H2020 green transition funding did **not** appear to offer any added value over other sources of funding. H2020 funding may still have been awarded to researchers with a propensity towards stronger achievements on these dimensions than at the EU27 average, however. The dimensions where specific H2020 added value was not found are:

- International co-publications, including international co-publications in different country breakdowns
- Cross-disciplinarity, in its interdisciplinary and multidisciplinary dimensions
- Share of academic-private co-publications, although here H2020 funding did successfully select researchers with a stronger tendency for this type of collaboration than the EU27 average
- Gender equity in research publication authorship, except in SC2 which saw the selection of researchers with strong overall achievements on this dimension (as compared to the EU27 average).
- Policy-related uptake of support research and its findings, except in SC2 which saw a differential gain on this dimension in supported publications as opposed to funded researchers' other publications
- Levels of online dissemination and outreach efforts (altmetrics dimensions), except for SC3-supported research which fostered differential gains on this dimension.

In the large majority of indicators included in the analysis (including those with negligible added value brought about by H2020 support), the DiD findings by SC were of equivalent effect sizes across the four SCs. This observation indicates that the effectiveness of H2020 funding in supporting publication-based outcomes was not likely not to be differentially modulated by SCs and their specific calls and support mechanisms, but generic to the whole of the H2020 programme instead. An implication of this synthesis observation for the interpretation of findings here is that publication-based achievements at the level of whole SCs are driven more by the features of the larger subfields covered by the thematic scope of the SCs than they are by the specific achievements linked to H2020.

A high-level narrative synthesis of bibliometric findings at SC level is provided below.

Table 23. Narrative synthesis of differential outcomes of H2020-green transition funding, by Societal Challenge and bibliometric dimension (2014-2021).

Bibliometric dimension	SC2	SC3	SC4	SC5
International collaboration	Slight H2020 diff. loss in Third country authorship	Slight H2020 diff. loss in Third country authorship	Slight H2020 diff. loss in Third country authorship	Slight H2020 diff. loss in Third country authorship
Cross-disciplinarity	Equivalent or inconclusive	Equivalent or inconclusive	Equivalent or inconclusive	Equivalent or inconclusive
Academic-private co-publication	° Higher caliber ° No H2020 diff. gain	° Higher caliber ° No H2020 diff. gain	° Higher caliber ° No H2020 diff. gain	° Higher caliber ° No H2020 diff. gain
Gender equity	° Higher caliber ° No H2020 diff. gain	Equivalent or inconclusive	Equivalent or inconclusive	Equivalent or inconclusive
Citation impact	° Higher caliber ° H2020 diff. gain	° Higher caliber ° H2020 diff. gain	° Higher caliber ° H2020 diff. gain	° Higher caliber ° H2020 diff. gain
Open access	° Higher caliber ° H2020 diff. gain	° Higher caliber ° H2020 diff. gain	° Equivalent caliber ° H2020 diff. gain	° Higher caliber ° H2020 diff. gain
Policy-related outcomes	° Higher caliber ° H2020 diff. gain	Equivalent or inconclusive	Equivalent or inconclusive	Equivalent or inconclusive
Online dissemination	Equivalent or inconclusive	° Equivalent caliber ° H2020 diff. gain	Equivalent or inconclusive	Equivalent or inconclusive

Note: Findings in grey are statistically inconclusive or equivalent between H2020 and counterfactual publications' performances. Findings in deep green see differential gains in scores for H2020 publications against counterfactual publications. Findings in light green see no differential gains in program publications against counterfactual ones, but both groups of publications score higher than the EU27 average (H2020-funded researchers are of a higher calibre than the EU27 average on this dimension). Findings in light red saw differential decreases for supported publications against counterfactual publications.

Source: Narrative processing of findings obtained from a Scopus implementation by Science-Metrix (Elsevier), eCorda

The logic of how counterfactual findings signal the relative homogeneity of findings across SC-level aggregates of journal publications can be illustrated with an example. SC3.2 research recorded a paper-level average share of women authors of slightly more than 40%. This compares to a proportion of 17% of women authors in SC3.5 publications. Despite this, we cannot conclude that H2020 funding has been more effective at promoting gender equity in SC2 than in SC4. The baseline proportion of women authors in SC2 subfields was already 39%, while it was 15% in SC4. Therefore, we can say that Food security-related subfields of research are much more likely to see gender equity in authorship than climate science-related subfields, but we must conclude that H2020 support has had negligible outcomes on gender equity in authorship for both SC2 and SC4.

Adding a comparison to the EU27 (non-FP-funded) baseline provides another informative comparison. SC2-funded researchers did not write journal publications with a differential increase in the share of women authorships, but they did include women authors more than at the EU27 average (where 35% of authorships were taken up by women on average in thematically aligned publications). This observation signals that H2020 calls were successful in selecting researchers with a higher tendency to integrate women co-authors than other EU27 researchers, even if H2020 funding did not result in a differential gain on this dimension. There are a few exceptions to this high-level conclusion. There is more differentiation in the differential gains brought about by H2020 support in DiD findings on the dimensions of citation impact and policy-related, patent, journalistic or social media impact of the research. These differences amongst SCs are not statistically definitive, however.

One statistically robust lead amongst SCs can be found on the dimension of open-access publishing, for SC3 against SC4 and SC5. Here, H2020 support enabled a differential gain of 20 percentage points in the share of publications made available by their authors under an OA modality. Comparable differential gains were of 12 percentage points instead for SC4 and SC5 publications. If improved support for OA as part of future green transition efforts is of interest, it may therefore be interesting to search for best practices in supporting this dimension within H2020 Energy research calls and instruments.

3.3. Full Societal Challenge-level counterfactual bibliometric findings

3.3.1. Societal Challenge-level counterfactual bibliometric findings on international collaboration

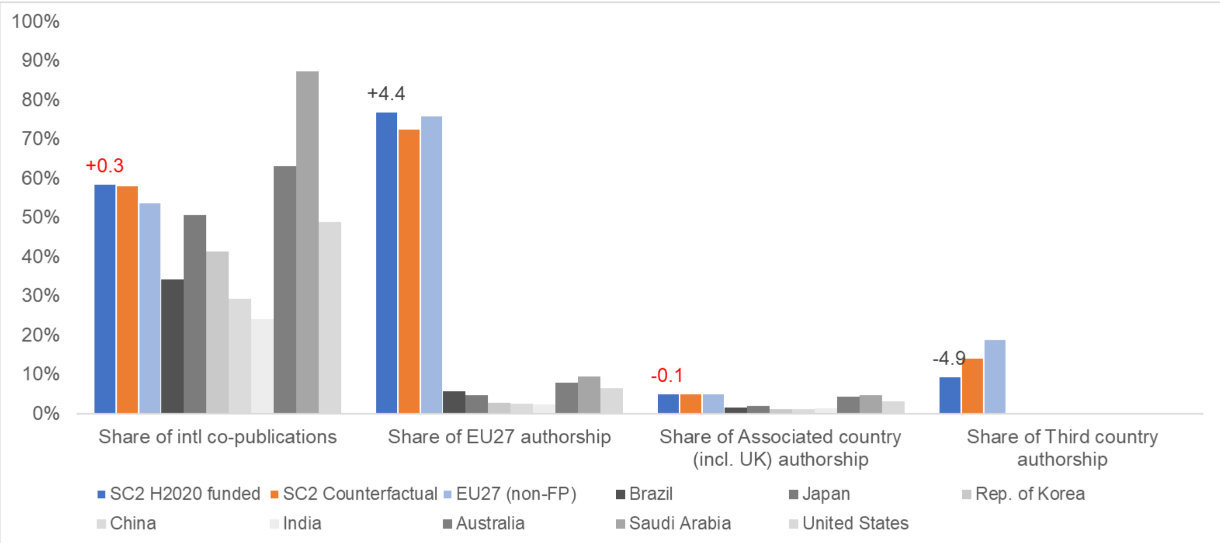


Figure 26. Differential changes in shares of international co-publication, Societal Challenge 2 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021)

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. Share of authorships: average publication-level share of authorships held by researchers from the country aggregate of interest. Shares of authorship do not add up to 100% as a result of control for biases in international co-publication counts otherwise amplified during the bootstrapping procedure.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

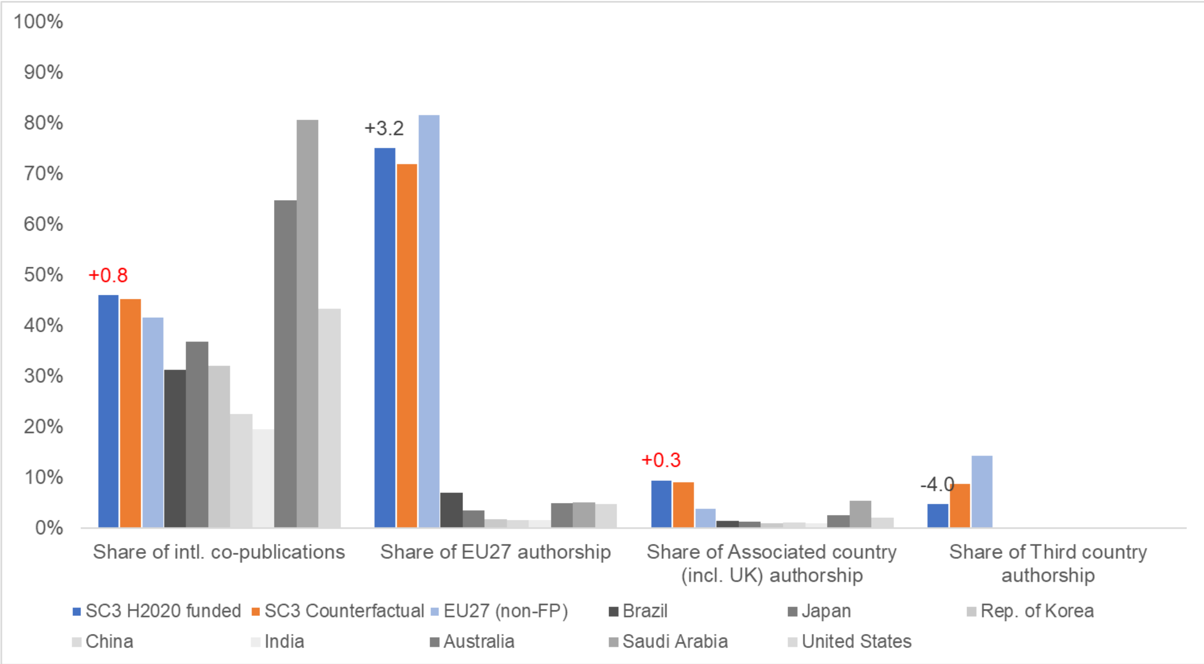


Figure 27. Differential changes in shares of international co-publication, Societal Challenge 3 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. Share of authorships: average publication-level share of authorships held by researchers from the country aggregate of interest. Shares of authorship do not add up to 100% as a result of control for biases in international co-publication counts otherwise amplified during the bootstrapping procedure.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

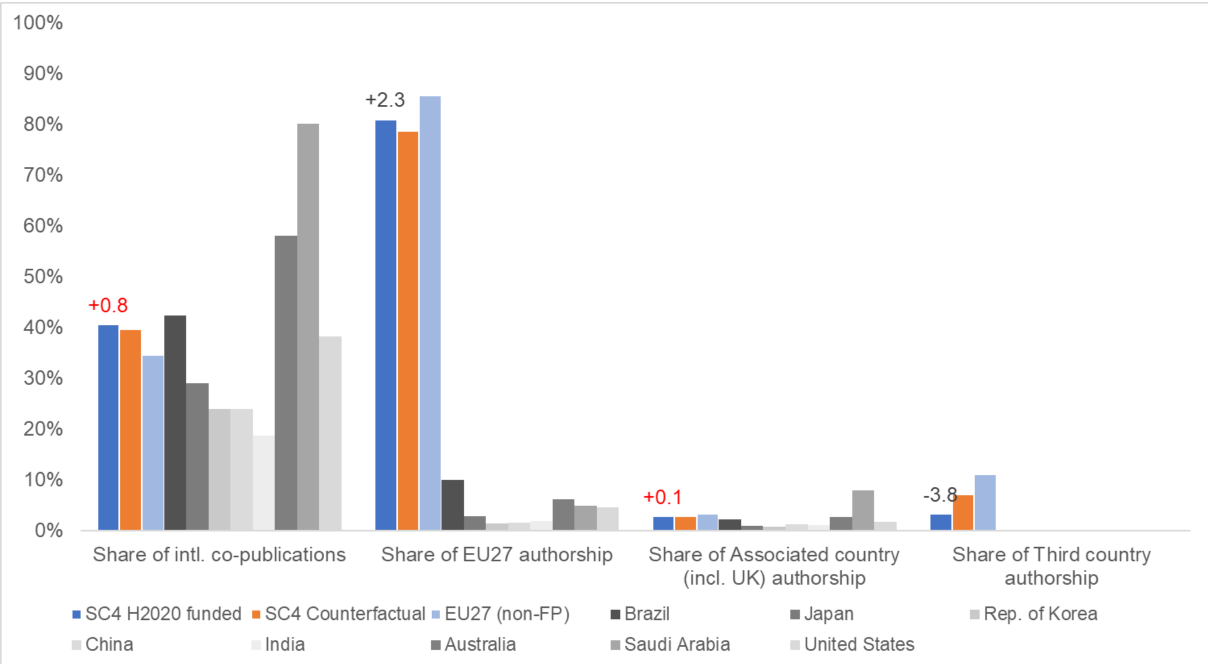


Figure 28. Differential changes in shares of international co-publication, Societal Challenge 4 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. Share of authorships: average publication-level share of authorships held by researchers from the country aggregate of interest. Shares of authorship do not add up to 100% as a result of control for biases in international co-publication counts otherwise amplified during the bootstrapping procedure.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

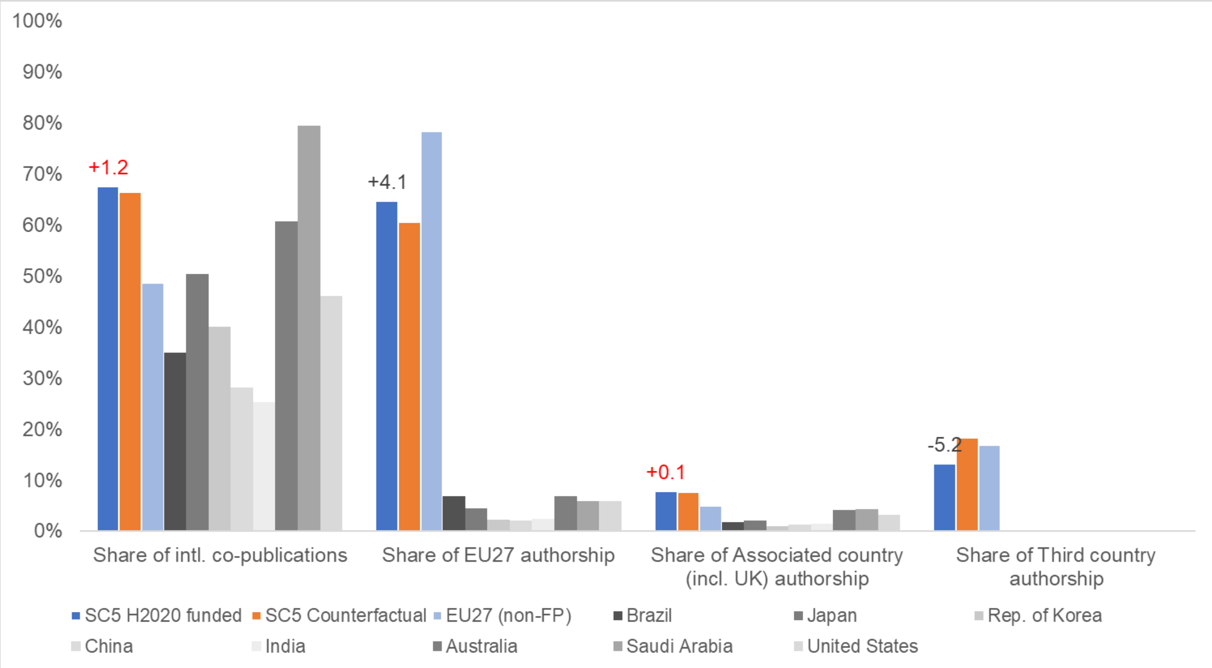


Figure 29. Differential changes in shares of international co-publication, Societal Challenge 5 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. Share of authorships: average publication-level share of authorships held by researchers from the country aggregate of interest. Shares of authorship do not add up to 100% as a result of control for biases in international co-publication counts otherwise amplified during the bootstrapping procedure.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

3.3.2. Societal Challenge-level counterfactual bibliometric findings on academic-private collaboration and gender equity in authorship

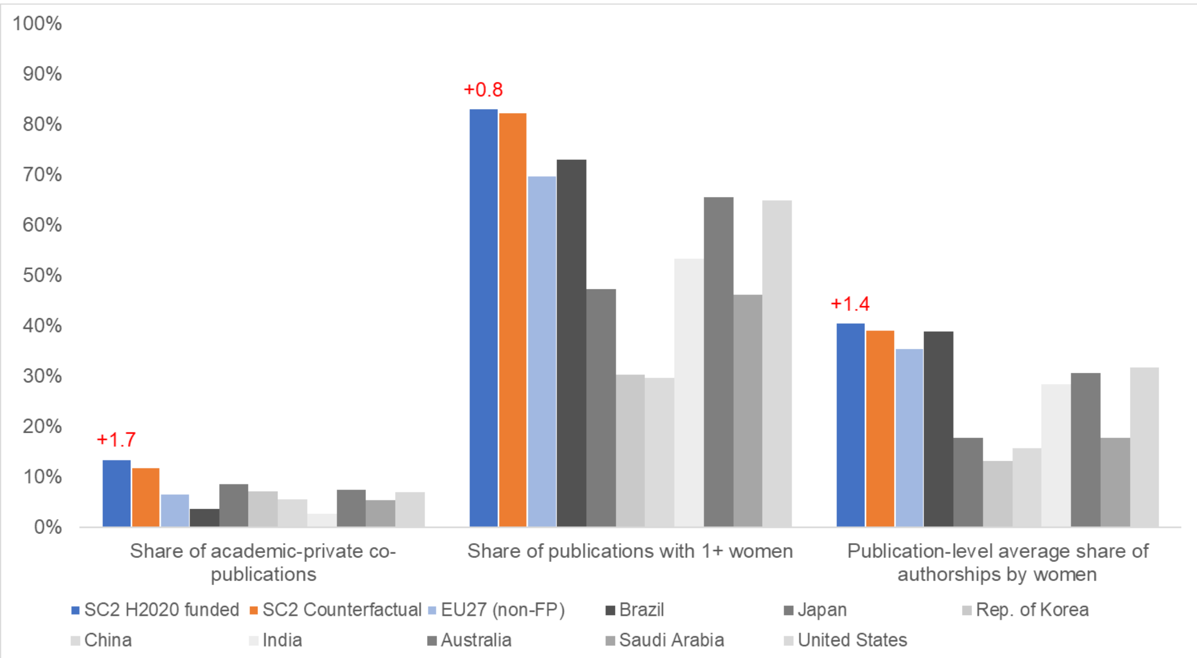


Figure 30. Differential changes in shares of academic-private co-publication and in gender equity in authorship, Societal Challenge 2 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier), eCorda and NamSor

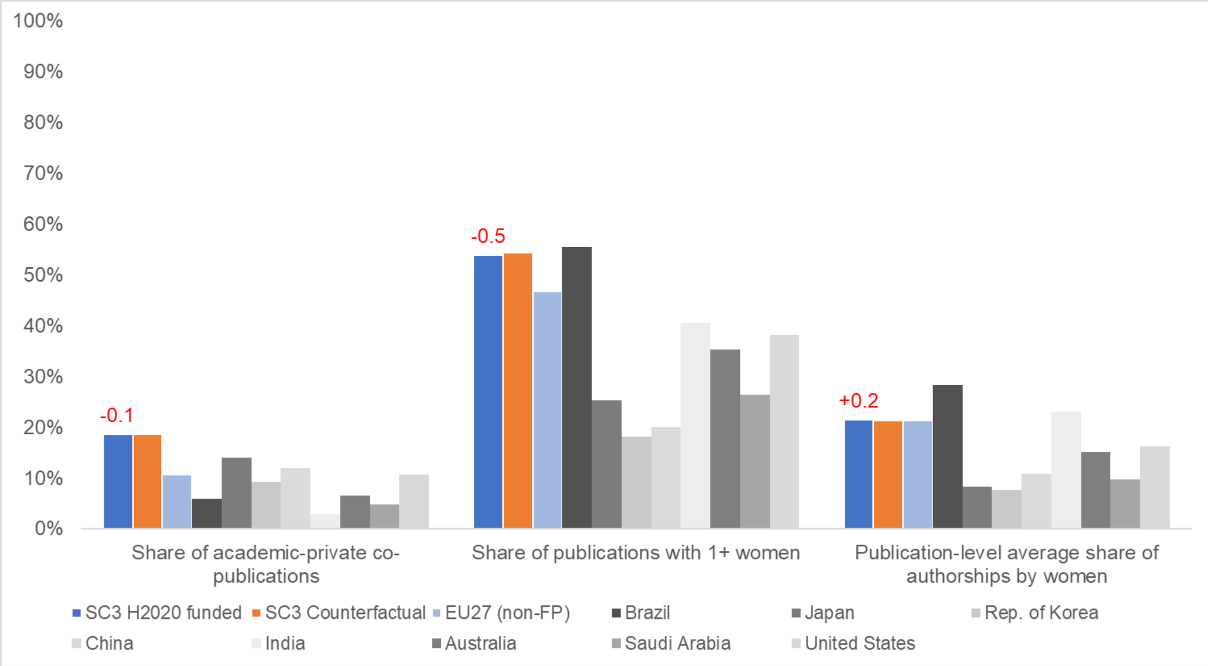


Figure 31. Differential changes in shares of academic-private co-publication, and in gender equity in authorship, Societal Challenge 3 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier), eCorda and NamSor

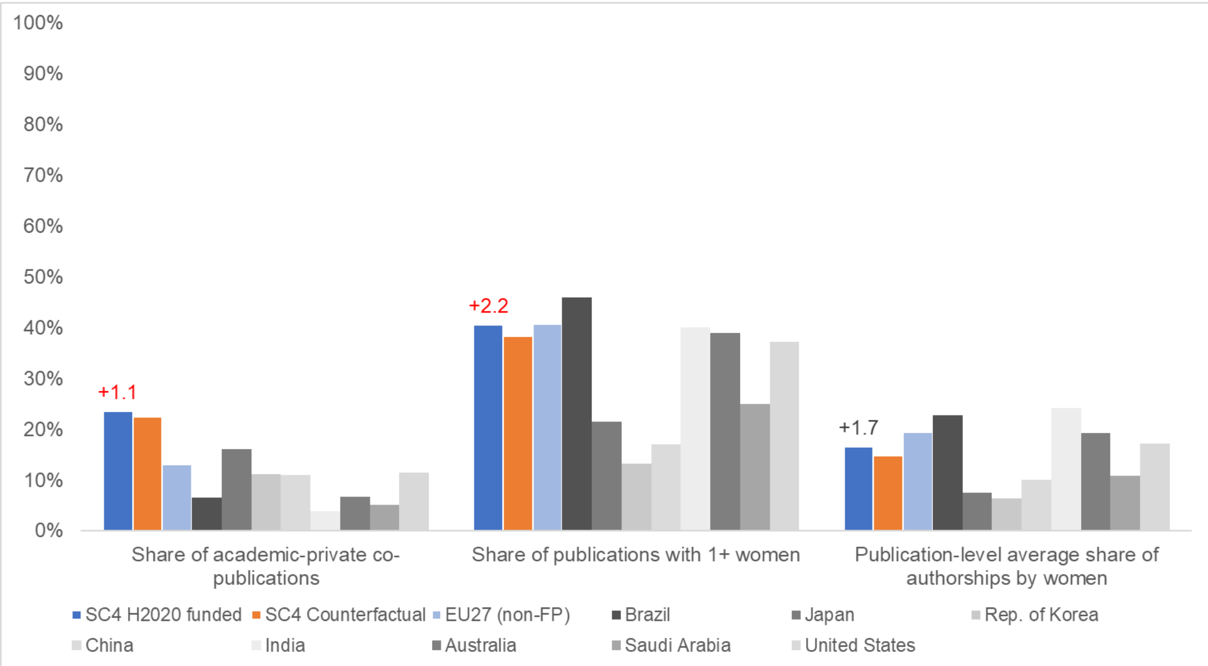


Figure 32. Differential changes in shares of academic-private co-publication, and in gender equity in authorship, Societal Challenge 4 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier), eCorda and NamSor

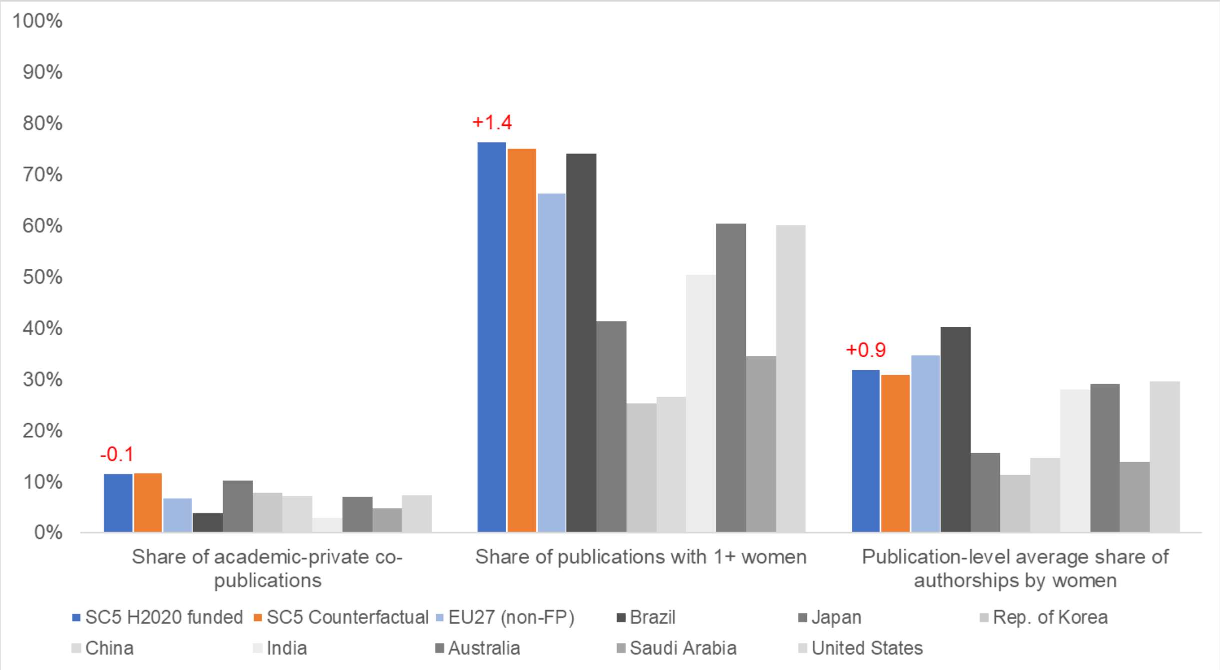


Figure 33. Differential changes in shares of academic-private co-publication, and in gender equity in authorship, Societal Challenge 5 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier), eCorda and NamSor

3.3.3. Societal Challenge-level counterfactual bibliometric findings on cross-disciplinarity

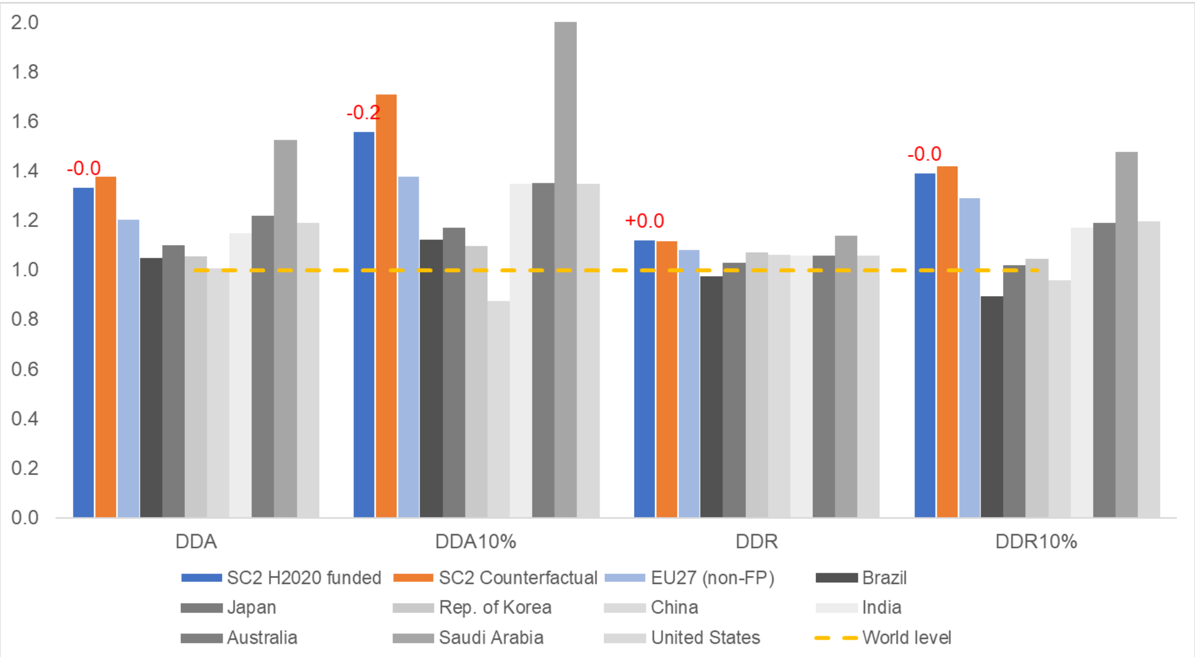


Figure 34. Differential changes in cross-disciplinarity in Societal Challenge 2 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. DDA: diversity in the disciplinary background of authors, capturing the relative collaborative multidisciplinarity of authors from different backgrounds working together. DDA10%: share of publications falling the top decile of most multidisciplinary publications in their subfield and year. DDR: disciplinary diversity in references of publication, capturing conceptual integration of prior findings from diverse subfields. Differential changes in red are not statistically definitive.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

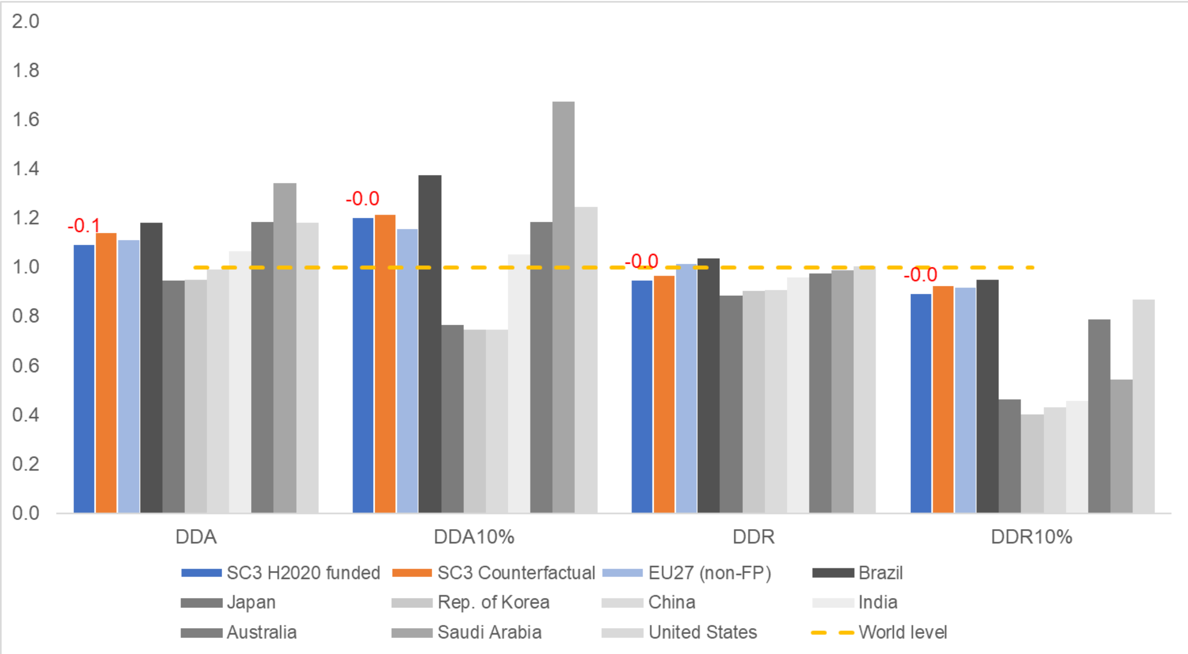


Figure 35. Differential changes in cross-disciplinarity in Societal Challenge 3 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. DDA: diversity in the disciplinary background of authors, capturing the relative collaborative multidisciplinarity of authors from different backgrounds working together. DDA10%: share of publications falling the top decile of most multidisciplinary publications in their subfield and year. DDR: disciplinary diversity in references of publication, capturing conceptual integration of prior findings from diverse subfields. Differential changes in red are not statistically definitive.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

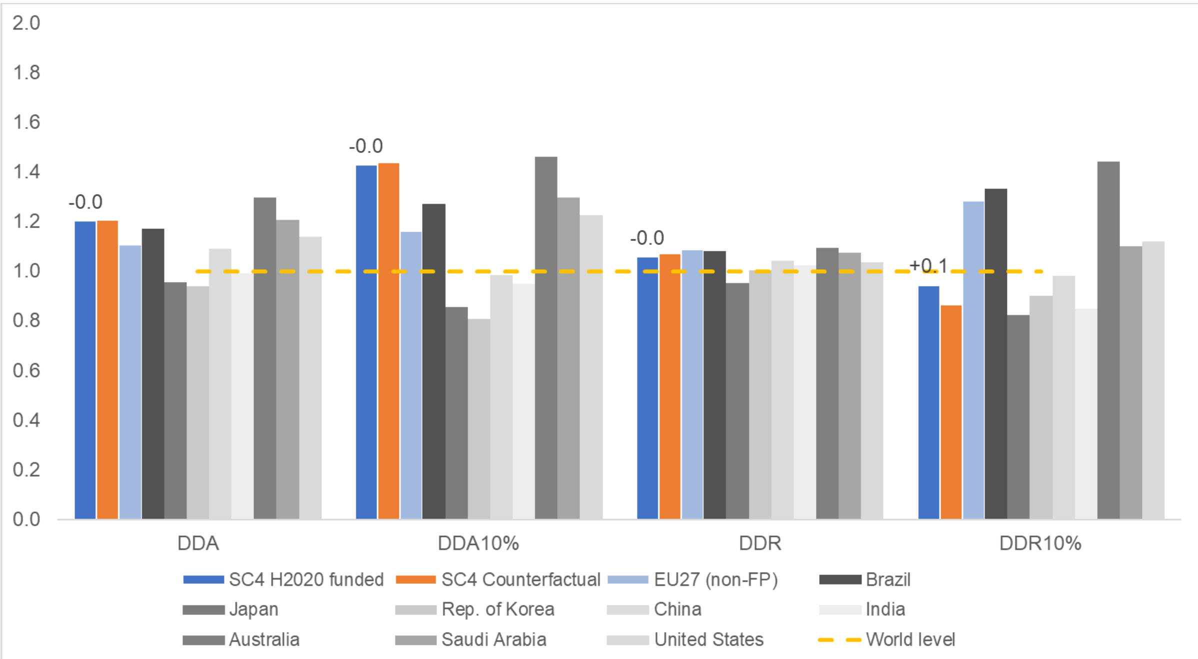


Figure 36. Differential changes in cross-disciplinarity in Societal Challenge 4 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. DDA: diversity in the disciplinary background of authors, capturing the relative collaborative multidisciplinarity of authors from different backgrounds working together. DDA10%: share of publications falling the top decile of most multidisciplinary publications in their subfield and year. DDR: disciplinary diversity in references of publication, capturing conceptual integration of prior findings from diverse subfields. Differential changes in red are not statistically definitive.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

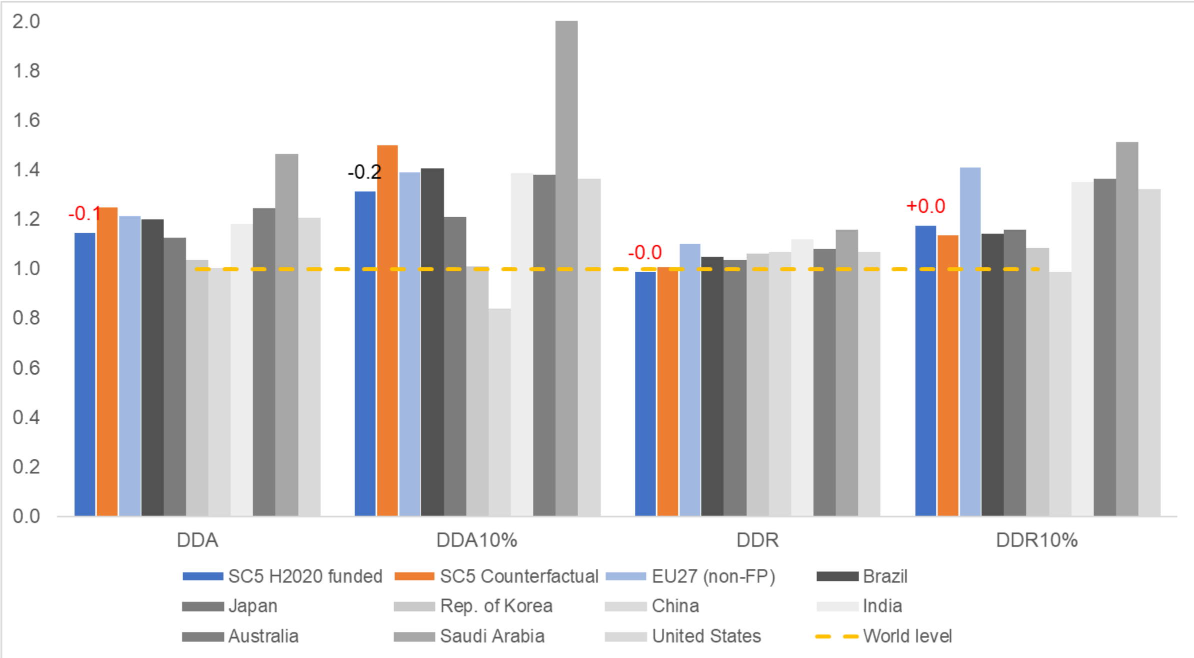


Figure 37. Differential changes in cross-disciplinarity in Societal Challenge 5 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. DDA: diversity in the disciplinary background of authors, capturing the relative collaborative multidisciplinarity of authors from different backgrounds working together. DDA10%: share of publications falling the top decile of most multidisciplinary publications in their subfield and year. DDR: disciplinary diversity in references of publication, capturing conceptual integration of prior findings from diverse subfields. Differential changes in red are not statistically definitive.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

3.3.4. Societal Challenge-level counterfactual bibliometric findings on citation impact

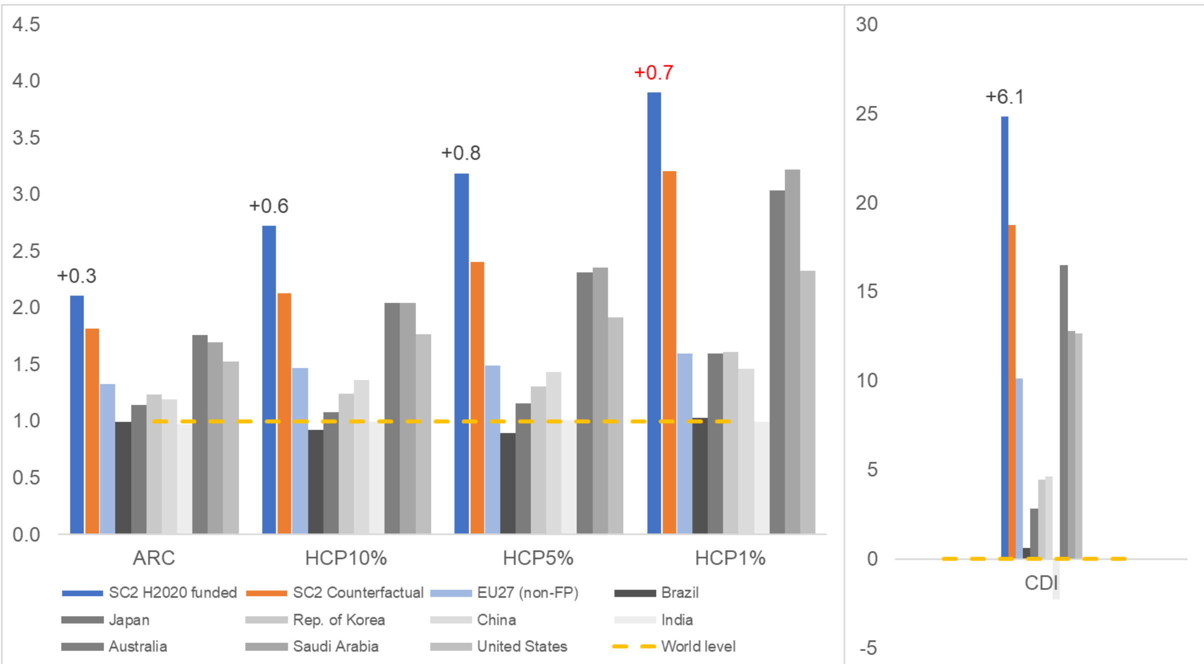


Figure 38. Differential changes in citation impact profiles in Societal Challenge 2 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. ARC: Average of relative citations. CDI: Citation distribution index. HCP10%: Share of highly cited publications (10% threshold); HCP5%: Share of highly cited publications (5% threshold). HCP1%: Share of highly cited publications (1% threshold).

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

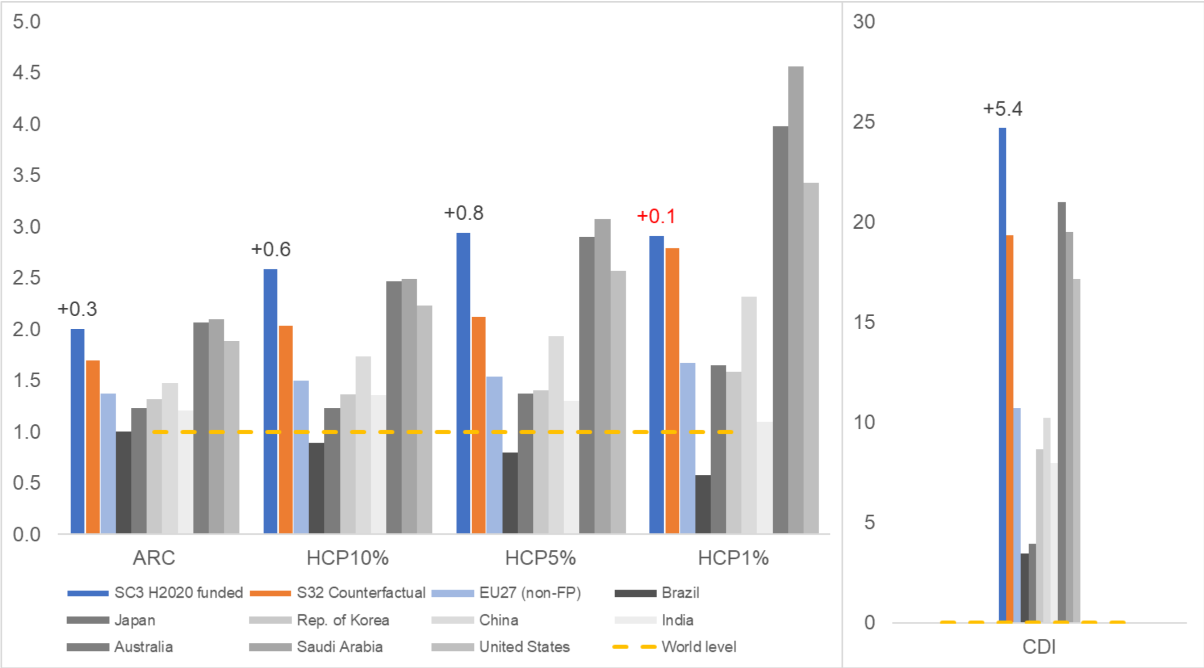


Figure 39. Differential changes in citation impact profiles in Societal Challenge 3 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. ARC: Average of relative citations. CDI: Citation distribution index. HCP10%: Share of highly cited publications (10% threshold); HCP5%: Share of highly cited publications (5% threshold). HCP1%: Share of highly cited publications (1% threshold).

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

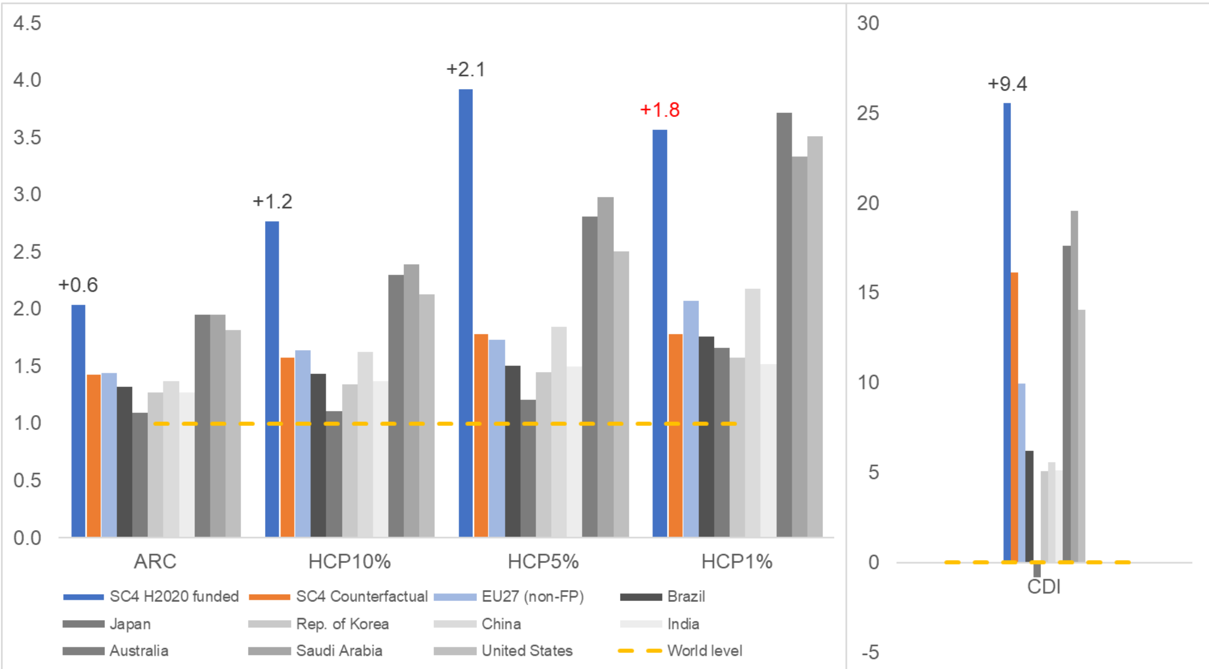


Figure 40. Differential changes in citation impact profiles in Societal Challenge 4 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. ARC: Average of relative citations. CDI: Citation distribution index. HCP10%: Share of highly cited publications (10% threshold); HCP5%: Share of highly cited publications (5% threshold). HCP1%: Share of highly cited publications (1% threshold).

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

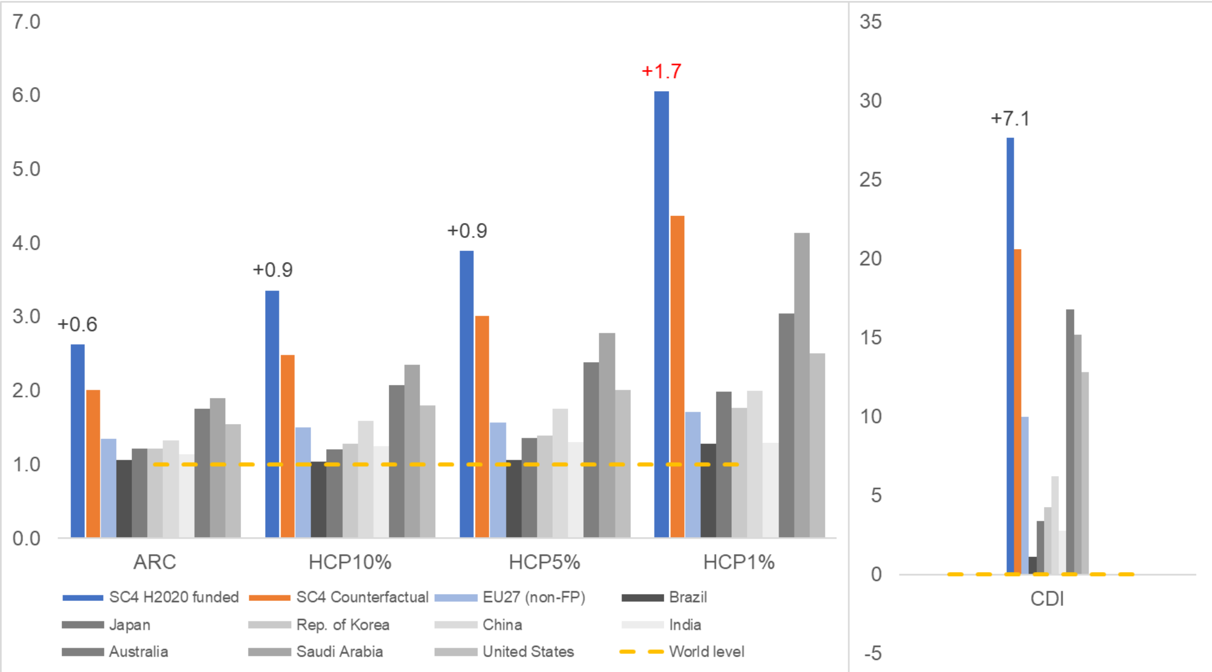


Figure 41. Differential changes in citation impact profiles in Societal Challenge 5 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative. ARC: Average of relative citations. CDI: Citation distribution index. HCP10%: Share of highly cited publications (10% threshold); HCP5%: Share of highly cited publications (5% threshold). HCP1%: Share of highly cited publications (1% threshold).

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

3.3.5. Societal Challenge-level counterfactual bibliometric findings on open-access publishing

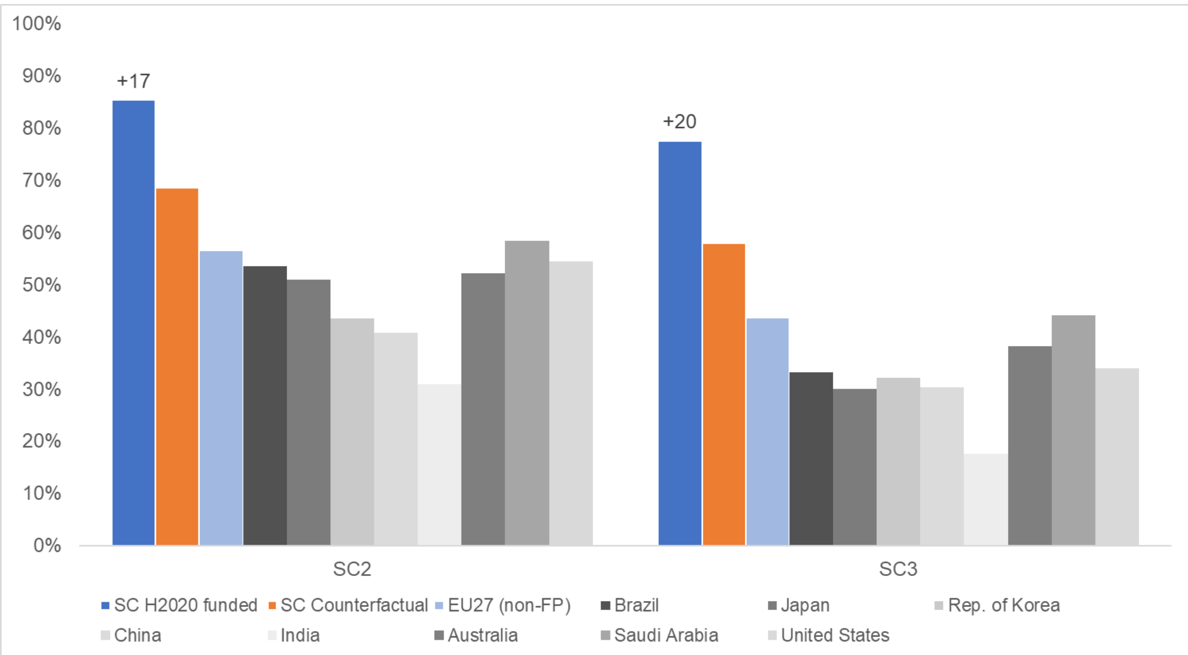


Figure 42. Differential changes in open access availability in Societal Challenge 2 and Societal Challenge 3 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) eCorda, and Unpaywall

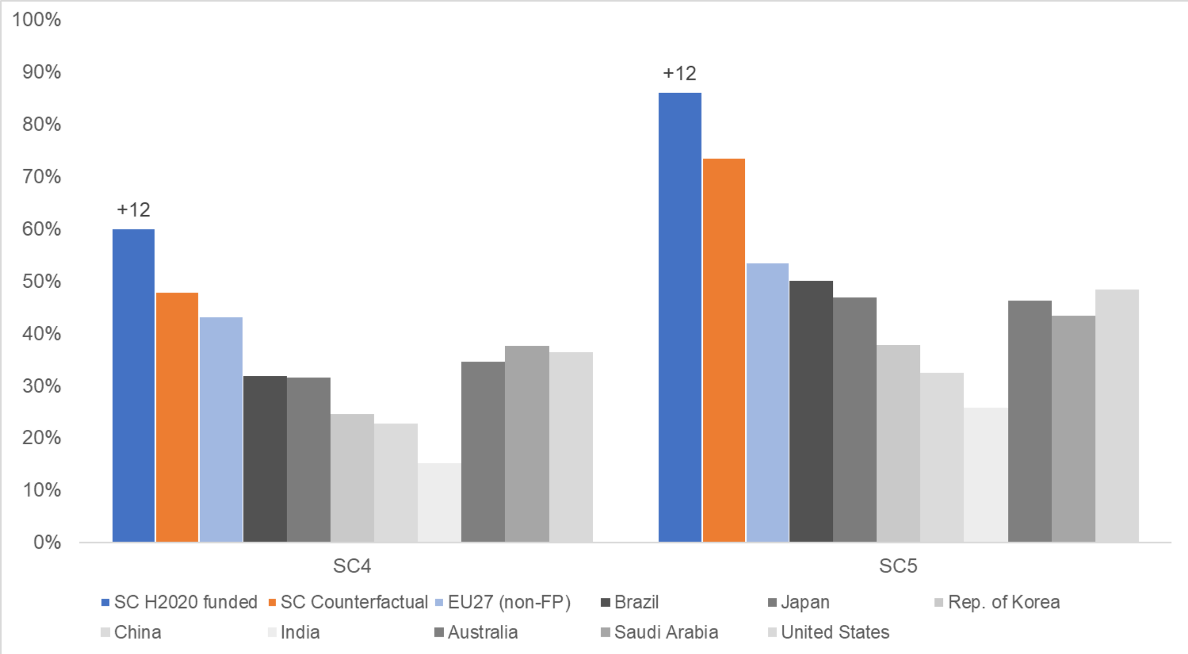


Figure 43. Differential changes in open access availability in Societal Challenge 4 and Societal Challenge 5 publications against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) eCorda, and Unpaywall

3.3.6. Societal Challenge-level counterfactual bibliometric findings on policy-related uptake and online dissemination efforts

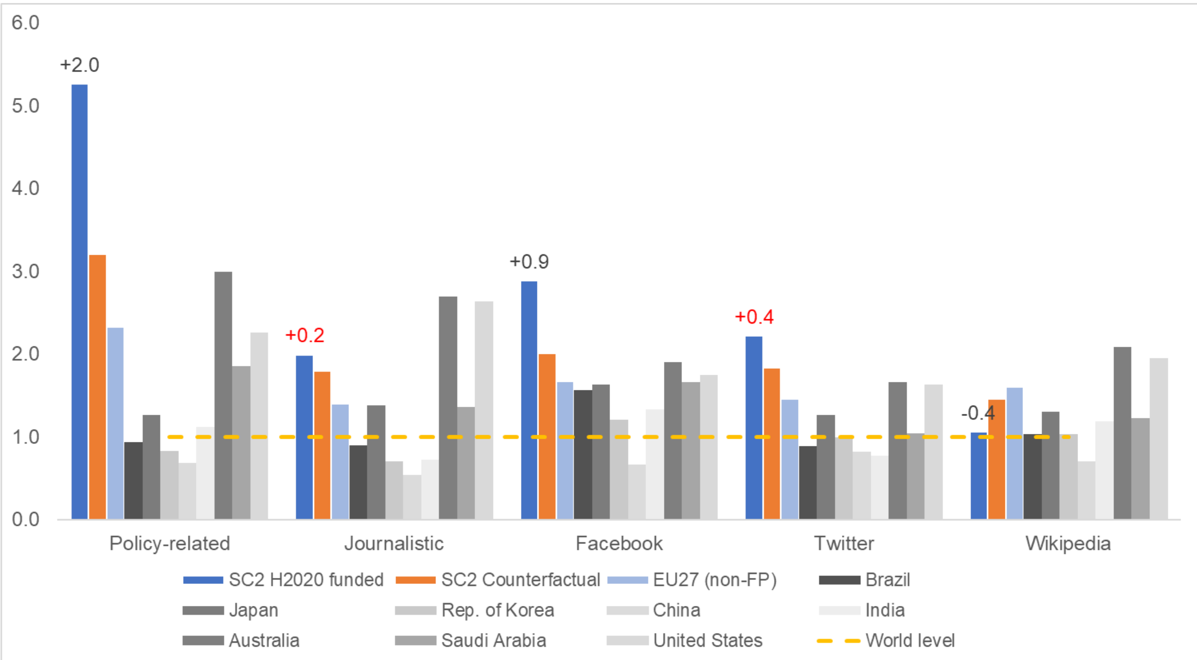


Figure 44. Differential changes in Societal Challenge 2 publications' uptake in policy-related documents, and online platforms against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) eCorda, Overton, and PlumX

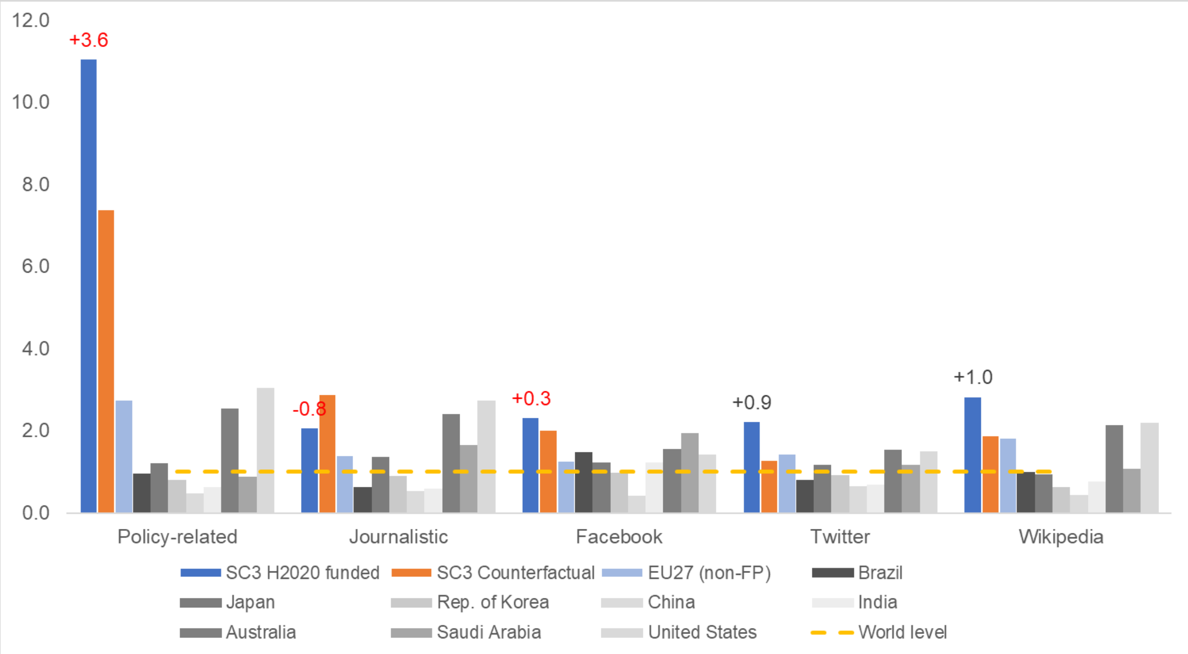


Figure 45. Differential changes in Societal Challenge 3 publications' uptake in policy-related documents, and online platforms against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) eCorda, Overton, and PlumX

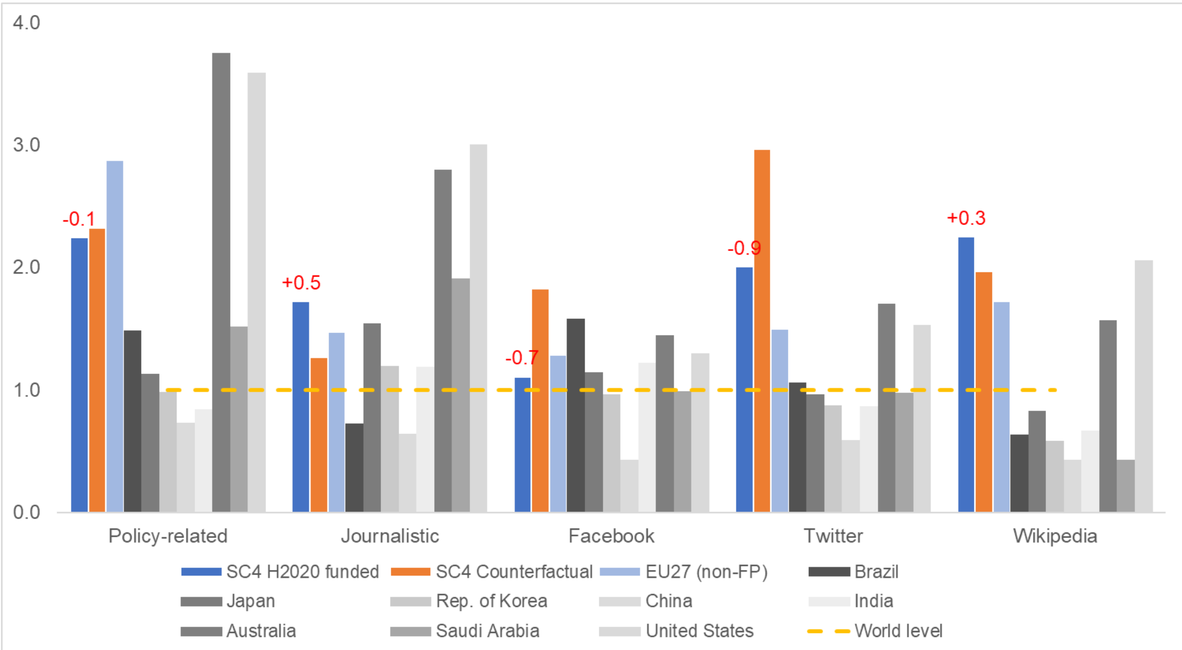


Figure 46. Differential changes in Societal Challenge 4 publications' uptake in policy-related documents, and online platforms against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) eCorda, Overton, and PlumX

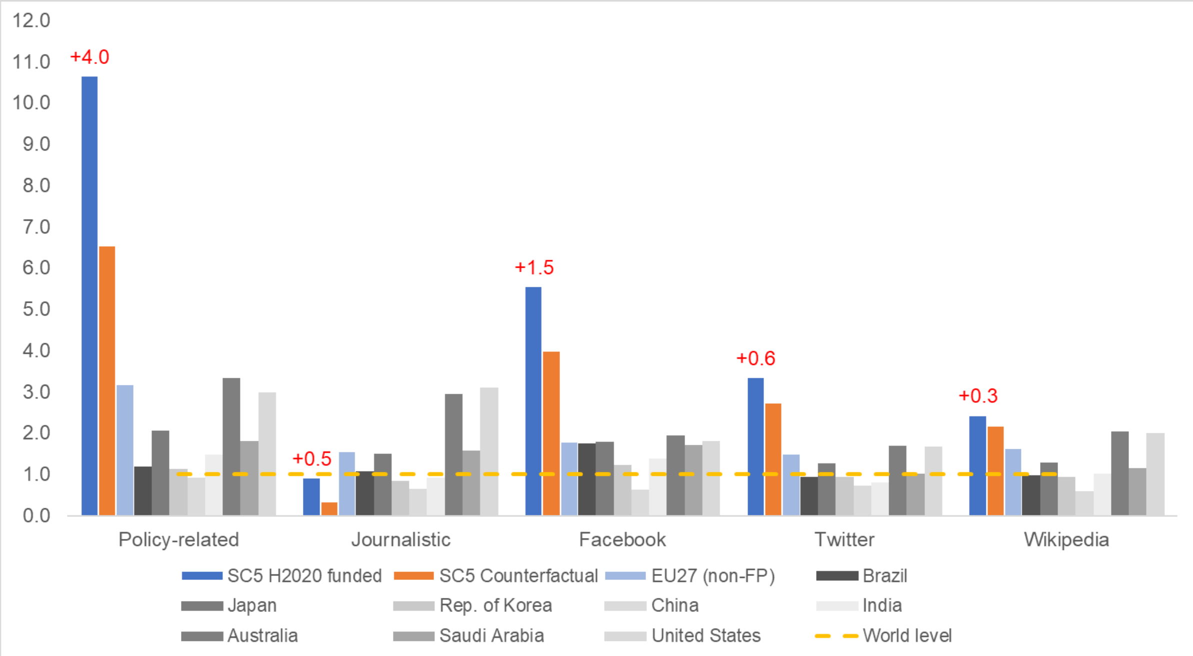


Figure 47. Differential changes in Societal Challenge 5 publications‘ uptake in policy-related documents, and online platforms against counterfactual publications, with the addition of EU27 average and international comparators (2014-2021).

Note: Results reported are point estimates from bootstrapping models. Differential scores in red are not statistically representative.

Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) eCorda, Overton, and PlumX

ANNEX VI: SYNOPSIS REPORT

1. Introduction

This report presents the synopsis of all stakeholder consultation activities undertaken under phase 1 of the Evaluation study on the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness - Focus on activities related to the green transition (hereafter referred to as ‘the Evaluation’) that took place from January 2022 to November 2022.

In line with the Better Regulation requirements, this report provides an outline of the consultation strategy, documents the consultation activities undertaken, identifies the stakeholder groups that participated and presents the methodology and tools used to process the collected data. For each consultation activity, results are summarized.

2. Consultation strategy

2.1. Objectives of the consultation

The elaboration of a consultation strategy is a key requirement when proceeding to information collection to support policymaking, notably when undertaking large evaluations. In compliance with Chapter 7 – Stakeholder Consultation of the 2021 'Better Regulation' toolbox, a consultation strategy was elaborated and validated during the inception phase of the evaluation to ensure an effective and efficient consultation process.

For this evaluation, the main objectives of consulting stakeholders were to:

- Gather views from relevant stakeholder groups to enrich the evaluation team’s knowledge and understanding of the subject matter of the evaluation.

- Contribute to the analysis of the aspects related to the relevance, coherence, effectiveness, efficiency, and EU-added value of the initiatives under assessment.

2.2. Stakeholder groups

To support the consultation strategy, the evaluators undertook a thorough mapping of the main stakeholder groups mapped according to their influence and stake, as well as the objectives for reaching out to them in terms of the information that they can provide.

The table below presents an overview of the main stakeholder groups.

Stakeholder group	Number of individuals
EC and subordinated bodies	
EC policy leads and delivery teams (Heads of unit, deputy heads of unit, specialists)	24
Policy officers representing programme parts of H2020 and organisations involved in the implementation, e. g. from the ERC, EIT, JRC, REA, CINEA, JUs etc	34
Senior officers of EU research and innovation representative bodies, including umbrella organisations representing applicant groups of H2020, e.g., Science Europe, NordForsk, ESF, ALLEA, EUCROF, EIRMA, ECSA, ECSITE, LERU, EUA, CESAER, EARTO	7
National and regional stakeholders	
MS and AC staff involved in 14 Programme Committees and other groups involved in the development of the Horizon 2020 Work Programmes and calls	3
Senior officers of national and regional research and innovation funding agencies	28
Senior officers of the national contact points and related network and information services	7
Representatives of applicants, beneficiaries, partnerships	
Applicants from HEIs / private companies / research institutes / CSOs / etc.	12
Horizon 2020, Horizon Europe beneficiaries	48
Representatives of partnerships funded under H2020 (PPPs and P2Ps)	24
Other stakeholders	
Experts (non-EC staff) involved in the development of the Horizon 2020 work programmes and calls, e.g., chairs and members of Advisory Groups, Foresight experts	13
Experts involved in the evaluation of proposals	2

2.3. Methods for stakeholder engagement

The consultation comprised six activity streams:

2.3.1. Scoping interviews

Dates	From January to April 2022
Number of persons contacted	40
Number of interviewees	20
Stakeholder group	- EC and subordinated bodies - Other stakeholders

2.3.2. Survey

Dates	From July to September 2022
Number of respondents	1,333 (of which 771 reached the end of the survey)
Stakeholder group	Representatives of applicants, beneficiaries, partnerships
Organisation	- By SC for relevance, effectiveness and EU added value. - All SC together for efficiency and the green transition process

2.3.3. Case studies

Dates	From February to November 2022
Number of cases	25
Stakeholder group	- EC and subordinated bodies - National and regional stakeholders - Representatives of applicants, beneficiaries, partnerships - Other stakeholders
Organisation	- 15 case studies - 10 partnerships studies (1 completed, 9 ongoing and delivered under phase 2)

2.3.4. International benchmarking

Dates	From April to November 2022

Number of cases	4
Stakeholder group	- National and regional stakeholders - Representatives of applicants, beneficiaries, partnerships - Other stakeholders
Organisation	- Efficiency and effectiveness (main focus) - Relevance (lesser extent) - Qualitative comparative assessment of H2020

2.3.5. Policy workshop

Dates	To be held on 12th January 2023
Number of participants	Information will be updated once the workshop takes place
Stakeholder group	Information will be updated once the workshop takes place

2.4. Data processing

All data collected, both quantitative and qualitative, have been thoroughly analysed. Figures and tables were produced and included in the main evaluation report and its appendixes. Data sources are indicated.

Quantitative inputs to the survey were analysed and disaggregated when needed. A specific appendix presents the results of the survey.

Where and when relevant, comparisons between the various data sources were undertaken.

The findings of this analysis are presented in the section below.

3. Results of the consultation process

The following section describes the main findings of the stakeholder consultation.

3.1. Scoping interviews

The main takeaways from the scoping interviews are presented as follows according to each evaluation criteria.

Relevance

- The process of co-creation allows a good involvement and endorsement of MSs and a good alignment of goals. It helped to refocus from the social-economic perspective to the more environmental one.
- During H2020, environmental objectives became increasingly relevant, and challenges were well addressed.
- The Green Deal allowed new environmental challenges to be included.

- HE also addressed emerging environmental topics. However, HE is rather new (2018-2020), and new events will certainly be included for the future WP (e.g., to consider the effects of the war in Ukraine).
- SC4: transport is a sector that lags in terms of green transition (compared for example to energy where several changes were seen like renewables). Only today, a transition in transport is occurring (electric cars, etc), which entails budgetary differences between sectors even though it is a topic of clear importance for the EC.
- A 'green transition' includes a broad range of complementary aspects, such as the reduction of greenhouse gas emissions to achieve climate neutrality, a reduction of harmful environmental impacts or biodiversity preservation, competitiveness in a global world, and a just transition to ensure social acceptability. Green transition is perceived by many as the necessary shift for achieving the overall objectives of the Commission, i.e., a climate-neutral economy in Europe by 2050 and all other associated objectives. Although only clearly framed under the European Green Deal in 2019, which is recognised as a clear (r)evolution in terms of comprehensiveness, consistency and priority, diagnostics leading to the need for green transition and related objectives were already existing before this strategy. This identification includes the preparatory phase of H2020, although in a more siloed, and less conceptualised, way and with a lower degree of priority. Interviewees also underline that while R&I is a component of the green transition, it constitutes only one out of the many necessary components for a successful transition to occur. Several interviewees noted that support for a green transition should not only focus on technological development, but also, for instance, on deployment. In H2020, the prioritisation of support to the green transition has evolved, as can be seen in the focus areas of the calls, whereby earlier calls further targeted socio-economic impacts and later calls increasingly targeted environmental aspects.
- There is limited flexibility as the green transition component is within a bigger framework. Budget and topics are allocated/defined in advance. However, some flexibility when countries are experiencing very high pressures.
- Regarding objectives of partnerships addressing key challenges as outlined in H2020:
    - During the second half of H2020, partnerships turned towards green and digital since the EU decided such topics were required/of interest.

Coherence

- Coherent in the topic of green transition, with policies being well aligned. The Green Deal served as a catalyser for new dynamics, but not necessarily new topics were included. More priority to green topics was given.
- Coherence with other parts of the FP relevant to the green transition: i) for HE, DG RTD ensured coherence since they have the overview of the programme. ii) in H2020, need to increase synergies between different projects which was addressed in HE (e.g., Mission approach). iii) H2020 was more precise than Horizon Europe; clusters are very big now.
- Also, with other parts of the FP non-relevant for the green transition, it requires improvement since it is perceived as a challenge.
- With other EU programmes serving similar objectives: need to ensure consistency between HE and other programmes, DG ENV and DG AGRI co-chair of cluster 6. Also, it was mentioned that different strategies and topics are coherent (e.g., with Farm-to-fork, or Biodiversity strategy).

Efficiency

- The funding for addressing needs in green transition is deemed enough/sufficient funds for SCs. Also, there are large amounts of funds being invested that will accelerate the changes significantly for SCs. However, a respondent mentioned that it would be required even more funds to tackle the issue of a green transition (limited financial capacity for the scale of the needs)
- Regarding barriers during the implementation:
    - Cost calculation under FP7 and H2020
    - Different conceptions of the role of research for sustainability: research as a driver for innovation (DG RTD) and policy framing innovation (DG AGRI)
- Regarding cost-effectiveness in the area of green transition:
    - H2020 and HE are considered to be efficient and successful examples of implementation.

- Funding was generous ranging from 70% to 100%
- Simplification of financial management: streamlined with lump sums.
- Digitalization was an improvement.
- Some smalls issues with new tools

Effectiveness

- H2020 allowed working on complex projects. Although, at this point, it is still too early to determine any long-term impacts of the projects funded to draw a trend. Hard to extrapolate results and know if they are due exclusively to H2020.
- H2020 contributed to climate science and policy (i.e., IPCC). And progress in research related to batteries and photovoltaics. Also, there have been successful examples that contributed to innovative solutions (e.g., HELIOS, green cars).
- The Programme was believed to be distant from the market even though there are indicators like patents, demonstrations, etc. Also, it was stated that the Programme focuses on policy, but there is a necessary time for industry and stakeholders (customers, citizens) to change.
- Capacity building is an overarching result of H2020.
- Blue Growth: the issue of pollution at sea was addressed. And ocean literacy was included in the agenda as well.
- Regarding the delivery of results as expected:
    - Impacts differ from MS, associated countries and third countries.
    - Only some projects were not completed successfully.
    - New technologies, new deep dives, made some pilots that work well, and some exhibitions.
- There is no specific monitoring framework for the green and digital transition.
- Some overlaps in parts of the programme: theoretically should be avoided during the design stage, but in practice not fully achieved. HE was simplified to tackle this.

3.2. Survey

The main findings resulting from the survey are presented below per societal challenge. Annex VII provides a detailed view of the survey results.

3.2.1. Societal Challenge 2 “Food, Agriculture, Water and Bioeconomy”

Relevance and coherence

In terms of technology and innovation, the two main **motivational drivers** for respondents are ‘addressing specific scientific or technical questions, problems and issues’ and ‘development of new processes, products and services’. ‘Accessing funding for seed research’ did not appear to be of the same importance. As far as climate and environment are concerned, ‘increasing resource efficiency in processes’ and the need ‘to address grand societal challenges related to climate’ were the biggest motivators for participation in the Framework Programmes. From a business and competitiveness point of view, ‘improving the visibility of the organisation’ exceeded significantly other motivational factors such as ‘increasing the productivity and competitiveness of the organisation’ and ‘diversification of the organisational activities’. Collaboration is a strong driver for participation in FPs, especially the 'development of new collaborations with other types of organisations' and much less so 'developing collaborations with non-EU organisations' and 'sharing the risks of a project'.

The needs and challenges of projects have been addressed to varying extents. *'Enabling sustainable exploitation of natural resources'* has been addressed to the highest extent. The challenges and needs which have been addressed to the lowest extent are the *'maximisation of social and economic benefits from Europe's oceans'* and *'provision of safe, healthy and affordable food*'.

Collaboration is key for H2020 projects, and its intensity was the highest with *Higher Education Institutions* and *Research Organisations* which exceeded by far collaboration with other types of stakeholders. On the other end of the spectrum, collaboration was lowest with *NGOs* and *Research Funding Organisations*.

With regards to **involving stakeholders** in the work of the projects, 40% considered this was done only partially. Covid-19 was a major reason for that. Moreover, certain groups were very difficult to engage such as big players in the food system or farmers. The difference between informing a stakeholder of the project's progress and simply informing them should be kept in mind. **Collaboration with non-EU partners** took place for less than half of the respondents but those who collaborated saw benefits from it the main one being *the 'development of know-how'*. *'Access to new markets'* has not been identified as a major benefit. Respondents are split with regards to the contribution of cooperation with non-EU partners on European position in global competitiveness: one-third considered this to be the case to a large and very large extent; one-third thought the impact was moderate and roughly one-third either did not know or were sceptical about that.

Effectiveness

According to survey responses, there is a high level of alignment between project objectives and results. From a **knowledge** perspective, the project contributed to the largest extent to *'knowledge and capacity building'* and *'scientific and technological development'*. 'Contribution to market and business development' has been the lowest. In terms of **scientific results**, respondents consider that the project contributed to the largest extent to *a 'better understanding of the subject'* and *'better access to state-of-the-art research'.*

With regards to **technology and innovation**, the share of respondents who consider results have been fully achieved or achieved to a large extent is lower than for knowledge- and science-related results. 'Expansion of basic knowledge for technological development' and 'New research tools, models, simulations' are the two technological development results which have been achieved to the highest extent. 'Cost reduction of technology' and 'increasing technology safety' have been achieved to the lowest extent. In terms of technological development outputs, the respondents identified 'More sustainable agriculture and forestry management' and 'Solutions across technology fields and sectors' as the biggest achievements. **System development results** are considered as achieved fully or to a large extent by no more than half of the respondents. 'Demonstration or pilot feasibility of technological solutions' and 'Integration of technology' are the system development results which have been achieved to the highest extent. However, different types of innovations in marketing and sales, and organizational and social innovations are on the low end.

The **TRL concept** has not been considered relevant by almost one-third of the respondents. The technology readiness for more than one-third of the projects was TRL2 and TRL3 at the start of the project. One quarter were TRL4 and TRL5, while TRL6 and higher were voiced by only 7% of the respondents. Data does not allow comparison between TRL levels at the start and the end of the same project. However, the fact that the number of TRL2 and TRL3 projects went down while TRL6, TRL7 and TRL 8 went up certainly means that overall, the projects increased their maturity level.

Organisational knowledge has been influenced to a large and very large extent for 21%-64% of the respondents, the largest focus being on 'intensified collaboration on R&D with new organisations' and 'increased focus on interdisciplinary research'. At the same time 'Increased focus on risk-oriented research' has been influenced by only one-fifth of the respondents. Around two-thirds of the respondents overwhelmingly validated the assumption that projects strengthened R&I capacities and EU excellence in science and innovation.

With regards to **coordination and collaboration**, four of the outcomes have been achieved to a large or very large extent by two-thirds of the respondents. These outcomes include cross-border and cross-sectoral integration; stronger pan-European collaboration across sectors; networks to address common challenges; and community and networks for improved stakeholder involvement.

Market and business have not been identified as a large or very large achievement by more than one-third of the respondents. 'Development of marketable products or services' and 'Creation of new jobs' are on the higher end, while 'Creation of start-ups and spin-offs' has been achieved to a large or very large extent by only 10% of the respondents. Almost 40% think the time-to-market of technological solutions has been improved. The impact of the programme on the microeconomic bottom line – turnover, employment, profit - of the projects funded is very limited. A slightly larger share of the respondents thinks the project improved their competitiveness, mostly in Europe and nationally and to a lesser extent – internationally. The relatively low level of perceived impact on market and business is also reflected in the perceived impact on different types of related outcomes. The outcomes 'Development of inclusive value chains' and 'Provision of competitive bio-based products' have been achieved to a large and very large extent by one-third of the respondents. At the same time, the outcome 'Removal of market barriers''

In terms of policies and standards, desired outcomes have been achieved to a large and very large extent by 21-37% of the respondents. Key policy outcomes such as 'More robust and transparent policy making' and 'More innovation conducive regulatory framework' have been achieved by around a third of the respondents. The outcome of improved standards has been achieved by a quarter of the respondents.

Different barriers impede project uptake to a varying degree, limited financial resources being the biggest obstacle followed by an impeding legal framework. It is positive that even for these two barriers the share of respondents hardly exceeds 25%.

A large majority of respondents think that **dissemination, exploitation and communication** activities have been both useful (76% to a large and very large extent) and sufficient (66%).

EU added-value

The main recognition of the EU value added lies in the fact that three-quarters of the respondents considered that without EU funding the project would not have been implemented or, if implemented, the scope would have been reduced. Naturally, in some cases, the project would have been funded at a later stage.

Moreover, respondents consider that H2020 projects added value in a multitude of aspects to varying degrees. Aspects which stand out with above 70% of respondents answering to a large or very large extent include 'The possibility to form multi-cultural consortia', 'The diversity of partners' profiles and coverage of various value chains', 'Providing funding opportunities for different topics' and 'Providing a good size of the project budget'.

The least value-added, still above 40% large and to a very large extent, is associated with 'Flexibility given to respond to technological developments', 'Flexibility given to respond to socio-economic needs' and 'possibility to conduct fundamental, exploratory or risky research'.

3.2.2. Societal Challenge 3 "Secure, clean and efficient energy"

Relevance and coherence

In terms of technology and innovation, the two main **motivational drivers** for respondents are 'addressing specific scientific or technical questions, problems and issues' and 'development of new processes, products and services'. 'Accessing funding for seed research' and 'Development of non-technological innovations' did not appear to be of the same importance. As far as climate and environment are concerned, 'Contribution to development that avoids GHG emissions and the need 'to address grand societal challenges related to climate' were the biggest motivators for participation in the Framework Programmes. From a business and competitiveness point of view, 'increasing the visibility of the organisation' exceeded significantly other motivational factors such as 'increasing the productivity and competitiveness of the organisation' and 'diversification of the organisational activities. Collaboration is a strong driver for participation in FPs, especially the 'development of new collaborations with other types of organisations' and much less so 'developing collaborations with non-EU organisations' and 'sharing the risks of a project'.

The needs and challenges of projects have been addressed to varying extents. *'Reducing energy consumption and carbon footprint'* has been addressed to the highest extent. The challenges and needs which have been addressed to the lowest extent are *'developing a single smart European electricity grid'* and *'making alternative fuels and energy sources more competitive'*.

Collaboration is key for H2020 projects, and its intensity was the highest with *Research Organisations* and *Higher Education Institutions* which exceeded by far collaboration with other types of stakeholders. On the other end of the spectrum, collaboration was lowest with *Research Funding Organisations* and *NGOs*.

With regards to **involving stakeholders** in the work of the projects, 71% of respondents believed that all relevant stakeholder groups were addressed. 27% considered this was done only partially. Identified reasons for this are diverse, ranging from the effects of Covid-19 to lacking time and resources or disinterest on the stakeholder side. A coherent and continuously updated stakeholder engagement strategy has proven to be a remedy according to some respondents. **Collaboration with non-EU partners** took place for roughly a fourth of the respondents but those who collaborated saw benefits from it the main one being *the 'development of know-how'*. *'Access to new markets'* has not been identified as a major benefit. Respondents are split with regards to the contribution of cooperation with non-EU partners on European position in the global competition: More than one-third considered this to be the case to a large and very large extent; roughly a fifth thought the impact was moderate, while the remaining respondents are either sceptical, convinced otherwise or do not know.

Effectiveness

According to survey responses, there is a high level of alignment between project objectives and results. From a **knowledge** perspective, the project contributed to the largest extent to *'knowledge and capacity building'* and *'scientific and technological development'*. The *'Contribution to market and business development'* has been the lowest. In terms of **scientific results**, respondents consider that the project contributed to the largest extent to *a 'better understanding of the subject'* and *'publications in peer reviewed journals'.*

With regards to **technology and innovation**, the share of respondents who consider results have been fully achieved or achieved to a large extent is lower than for knowledge- and science-related results. *'New research tools, models, simulations'* and *'Expansion of basic knowledge for technological development'* are the two technological development results which have been achieved to the highest extent. *'Increasing technology safety'* and *'Cost reduction of technology'* have been achieved to the lowest extent. In terms of **technological development outputs**, the respondents identified 'Solutions across technology fields and sectors' as the biggest achievement. On the other side of the spectrum, the outcome achieved to the least extent is 'Affordable and integrated energy storage solutions'. **System development results** are considered as achieved fully or to a large extent by no more than half of the respondents. *'Demonstration or pilot feasibility of technological solutions'* and *'Integration of technology'* are the system development results which have been achieved to the highest extent. However, social as well as marketing and sales innovations are on the low end.

The **TRL concept** has not been considered relevant by almost one-third of the respondents. The technology readiness for more than one-third of the projects was TRL2 and TRL3 at the start of the project. The overall TRL levels at the end of the projects do not reveal a significant difference although data does not allow comparison between TRL levels at the start and the end of the same project.

Organisational knowledge has been influenced to a large and very large extent for 20%-48% of the respondents, the largest focus being on *'intensified collaboration on R&D with new organisations'* and *'increased focus on interdisciplinary research*'. At the same time *'Increased focus on risk-oriented research'* has been influenced by only one-fifth of the respondents. Around half of the respondents validated the assumption that projects strengthened R&I capacities and EU excellence in science and innovation.

With regards to **coordination and collaboration**, no more than half of the respondents considered that their projects contributed to the different desired outcomes to a large or very large extent. '*Networks to address common challenge'* stands out as the most affected outcome while *'Stronger involvement of civil society in R&I'* constitutes the outcome to which projects have contributed the least.

Market and business have not been identified as a large or very large achievement by more than one-third of the respondents. 'Development of marketable products or services' and 'Market launch of new products or services' are on the highest end while 'Creation of start-ups and spin-offs have been achieved to a large or very large extent by less than 10% of the respondents. Almost 40% think the time-to-market of technological solutions has been improved. The impact of the programme on the microeconomic bottom line – turnover, employment, profit - of the projects funded is very limited.

EU added-value

The main recognition of the EU value added lies in the fact that three-quarters of the respondents considered that without EU funding the project would not have been implemented or, if implemented, the scope would have been reduced. Naturally, in some cases, the project would have been funded at a later stage.

Moreover, respondents consider that H2020 projects added value in a multitude of aspects to varying degrees. Aspects which stand out with above 70% of respondents answering to a large or very large extent include 'The possibility to form multi-cultural consortia', 'The diversity of partners' profiles and coverage of various value chains', and 'Providing funding opportunities for specific topics'.

The least value-added, still over 30% large and to a very large extent, is associated with 'Flexibility given to respond to socio-economic needs' and 'technical support provided'.

3.2.3. Societal Challenge 4 "Smart, Green and Integrated Transport"

Relevance and coherence

In terms of technology and innovation, the two main **motivational drivers** for respondents are 'addressing specific scientific or technical questions, problems and issues' and 'development of new processes, products and services'. 'Accessing funding for 'seed' research' did not appear to be of the same importance. As far as climate and environment are concerned, 'Contribution to development that avoids GHG emissions' and 'Addressing grand societal challenges related to the climate' were the biggest motivators for participation in the Framework Programmes. From a business and competitiveness point of view, 'improving the visibility of the organisation' exceeded other motivational factors such as 'increasing the productivity and competitiveness of the organisation' and 'diversification of the organisational activities'. Collaboration is a strong driver for participation in FPs, especially the 'development of new collaborations with other types of organisations' and much less so 'sharing the risks of a project' and 'developing collaborations with non-EU organisations'.

The needs and challenges of projects have been addressed to varying extents. *'Making transport more sustainable and respecting the environment'* has been addressed to the highest extent. The challenges and needs which have been addressed to the lowest extent are *'decreasing traffic congestion', 'making transport and transport systems seamless'* and *'performing socio-economic research and forward-looking activities for policy making'.*

Collaboration is key for H2020 projects and its intensity was the highest with *Research Organisations* and *Higher Education Institutions* which exceeded by far collaboration with other types of stakeholders. On the other end of the spectrum, collaboration was lowest with *NGOs* and *Research Funding Organisations*.

With regards to **involving stakeholders** in the work of the projects, 67% noted that all relevant stakeholders were addressed, while 40% thought this was done only partially. Identified reasons for this are diverse, ranging from the effects of Covid-19 or the Russian attack on Ukraine to lacking time and resources or disinterest on the stakeholder side. Additionally, respondents noted legal hurdles and data protection rules that hindered stakeholder collaboration. **Collaboration with non-EU partners** took place for less than a third of the respondents but those who collaborated saw benefits from it the main one being *the 'development of know-how'*. *'Access to new markets'* has not been identified as a major benefit. Respondents are split with regards to a positive contribution of cooperation with non-EU partners on the European position in the global competition: almost half consider this to be the case to a large and very large extent, while the remaining half is either in disagreement, does not know or considers it too early to tell.

Effectiveness

According to survey responses, there is a high level of alignment between project objectives and results. From a **knowledge** perspective, the project contributed to the largest extent to *'knowledge and capacity building'* and *'scientific and technological development'*. *'Contribution to market and business development'* has been the lowest. In terms of **scientific results**, respondents consider that the project contributed to the largest extent to a *'better understanding of the subject'* and *'better access to state-of-the-art research'.*

With regards to **technology and innovation**, the share of respondents who consider results have been fully achieved or achieved to a large extent is lower than for knowledge- and science-related results. *'New research tools, models, simulations'* and *'Expansion of basic knowledge for technological development'* are the two technological development results which have been achieved to the highest extent. *'Cost reduction of technology'* and *'Development and improvement* of *production processes'* have been achieved to the lowest extent. In terms of technological development outputs, the respondents identified *'New generation of innovative and environmentally friendly air, waterborne and land transport means'* and *'Solutions across technology fields and sectors'* as the biggest achievements. **System development results** are considered as achieved fully or to a large extent by no more than 58% of the respondents. '*Demonstration of pilot feasibility of technological solutions'* and *'Integration of technology'* are the system development results which have been achieved to the highest extent. However, different types of innovations in marketing and sales and organisational and social innovations are on the low end.

The **technology readiness** for half of the projects was TRL2 and TRL3 at the start of the project. The overall TRL levels at the end of the projects do not allow comparison between TRL levels at the start and the end of the same project. Nevertheless, it could be said that the reduced number of TRL2 and TRL3 projects and the steep increase in the number of TRL 7 and 4 and TRL7 projects means an overall gain in TRL level. The **TRL concept** has not been considered relevant by 14% of the respondents.

Organisational knowledge has been influenced to a large and very large extent for 22%-50% of the respondents, the largest focus being on *'intensified collaboration on R&D with new organisations'* and *'increased focus on interdisciplinary research'*. At the same time *'Increased focus on risk-oriented research'* has been influenced by only one-fifth of the respondents. Around half of the respondents validated the assumption that projects strengthened R&I capacities and EU excellence in science and innovation.

With regards to **coordination and collaboration**, four of the outcomes have been achieved to a large or very large extent by two-thirds of the respondents. These include cross-border and cross-sectoral integration; stronger pan-European collaboration across sectors; networks to address common challenges; and community and networks for improved stakeholder involvement.

Market and business have been identified as a large or very large achievement by less than half the respondents. *'Development of marketable products or services'* and *'Market launch of new products and services'* are on the highest end while *'Creation of start-ups and spin-offs'* have been achieved to a large or very large extent by less than 5% of the respondents. Almost 40% think the time-to-market of technological solutions has been improved. The impact of the programme on the microeconomic bottom line – turnover, employment, profit - of the projects funded is very limited. A slightly bigger share of the respondents thinks the project improved their competitiveness, mostly in Europe and nationally and to a lesser extent – internationally. The relatively low level of perceived impact on market and business is also reflected in the perceived impact on different types of related outcomes. The most successful outcome *'More competitive industry'* has been achieved to a large and very large extent by only 42% of the respondents.

In terms of policies and standards, desired outcomes have been achieved to a large and very large extent by 26-28% of the respondents. Key policy outcomes such as *'New transport standards'* and *'More robust and transparent policy making'* have been achieved by slightly more than a quarter of the respondents.

Different barriers impede project uptake to a varying degree, limited financial resources being the biggest obstacle followed by an impeding legal framework. It is positive that even for these two barriers the share of respondents does not exceed 29%.

A large majority of respondents think that **dissemination, exploitation and communication** activities have been both useful (71% to a large and very large extent) and sufficient (59%).

EU added-value

Between 36 and 79% of the respondents think that H2020 provided an EU-added value in several aspects to a large and very large extent. This is particularly the case regarding the *'diversity of partner profiles'* followed by the *'multi-cultural aspects of the consortia'* and *'funding opportunities for specific topics'.* On the other end, 'Technical support provided' has been the lowest. An overwhelming majority of respondents answered that the project would have been implemented with a reduced scope without support from H2020.

3.2.4. Societal Challenge 5 "Climate action, environment, resource efficiency and raw materials"

Relevance and coherence

In terms of technology and innovation, the two main **motivational drivers** for respondents are 'addressing specific scientific or technical questions, problems and issues' and 'development of new processes, products and services'. 'Accessing funding for seed research' did not appear to be of the same importance. As far as climate and environment are concerned, 'increasing resource efficiency in processes' and the need 'to address grand societal challenges related to climate' were the biggest motivators for participation in the Framework Programmes. From a business and competitiveness point of view, 'improving the visibility of the organisation' exceeded significantly other motivational factors such as 'increasing the productivity and competitiveness of the organisation' and 'diversification of the organisational activities'. Collaboration is a strong driver for participation in FPs, especially the 'development of new collaborations with other types of organisations' and much less so 'developing collaborations with non-EU organisations' and 'sharing the risks of a project'.

The needs and challenges of projects have been addressed to varying extents. '*Protection of the environment, sustainably managing natural resources, water, biodiversity and ecosystems'* has been addressed to the highest extent. The challenges and needs which have been addressed to the lowest extent are 'Protecting cultural heritage from climate change damage and maximising its opportunities for economic growth' and 'Developing comprehensive and sustained global environmental observation and information systems, including Earth Observation'.

Collaboration is key for H2020 projects, and its intensity was the highest with *Higher Education Institutions* and *Research Organisations* which exceeded by far collaboration with other types of stakeholders. On the other end of the spectrum, collaboration was lowest with *NGOs* and *Research Funding Organisations*.

With regards to **involving stakeholders** in the work of the projects, 35% considered this was done only partially. It was noted that having a well-equipped outreach team was a barrier to involving stakeholders effectively. Also, Covid-19 was a major reason. Varying the communication channels, also in scope and depth, for the sake of reaching different target audiences was found to be beneficial to reach stakeholders.

Collaboration with non-EU partners took place for less than half of the respondents but those who collaborated saw benefits from it the main one being *the 'development of know-how'*. *'Access to new markets'* has not been identified as a major benefit. Respondents are split with regards to the contribution of cooperation with non-EU partners on European position in global competitiveness: 44% considered this to be the case to a large and very large extent; one-third thought the impact was moderate and 12% either did not know or were sceptical about that.

Effectiveness

According to survey responses, there is a high level of alignment between project objectives and results. From a **knowledge** perspective, the project contributed to the largest extent to *'knowledge and capacity building'* and *'scientific and technological development'*. *'Contribution to market and business development'* has been the lowest. In terms of **scientific results**, respondents consider that the project contributed to the largest extent to *a 'better understanding of the subject'* and *'better access to state-of-the-art research'.*

With regards to **technology and innovation**, 'New research tools, models, simulations' and 'New databases, platforms and test beds' are the two technological development results which have been achieved to the highest extent. 'Cost reduction of technology' and 'increasing technology safety' have been achieved to the lowest extent. In terms of technological development outputs, the respondents identified 'New or improved technologies and services accelerating transformation towards climate neutrality' and 'Strengthened eco-innovative technologies, processes and services' as the biggest achievements. **System development results** are considered as achieved fully or to a large extent by 18% to 57% of the respondents. 'Demonstrate or pilot feasibility of technological solutions', 'Development of proposals for the further development of technological systems', and "Integration of technology' are the system development result which has been achieved to the highest extent. However, different types of innovations in marketing and sales are on the low end.

The **TRL concept** has not been considered relevant by almost one-quarter of the respondents. The technology readiness for almost half of the projects was TRL2 and TRL3 at the start of the project. 15% were TRL4 and TRL5 while TRL6 and higher were voiced by only 13% of the respondents. The overall TRL levels at the end of the projects reveal a significant increase in levels although data does not allow comparison between TRL levels at the start and the end of the same project.

Organisational knowledge has been influenced to a large and very large extent for 33%-63% of the respondents, the largest focus being on 'increased focus on interdisciplinary research'. At the same time 'Increased focus on risk-oriented research' has been influenced by the least respondents.

With regards to **coordination and collaboration**, four of the outcomes have been achieved to a large or very large extent by two-thirds of the respondents. These include cross-border and cross-sectoral integration; stronger pan-European collaboration across sectors; networks to address common challenges; and community and networks for improved stakeholder involvement.

In terms of market and business, 'Development of marketable products or services is on the highest end while Creation of start-ups and spin-offs have been achieved to a large or very large extent by only 5-8% of the respondents. More than half of the respondents think the time-to-market of technological solutions has been improved. The impact of the project on the microeconomic bottom line – turnover, employment, profit - of the project is very limited. A slightly bigger share of the respondents believes the project improved their competitiveness, mostly in Europe and nationally and to a lesser extent – internationally. The relatively low level of perceived impact on market and business is also reflected in the perceived impact on different types of related outcomes. The outcome 'Higher consumer awareness and acceptance' has been achieved to a large and very large extent by almost one-third of the respondents.

In terms of policies and standards, desired outcomes have been achieved to a large and very large extent by 25-42% of the respondents. Key policy outcomes such as 'More robust and transparent policy making' have been achieved by around a third of the respondents.

Different barriers impede project uptake to a varying degree, limited financial resources being the biggest obstacle followed by 'Lack of internal organisational support for implementation'. It is positive that even for these two barriers the share of respondents hardly exceeds 30%.

The huge majority of respondents think that **dissemination, exploitation and communication** activities have been both useful (76% to a large and very large extent) and sufficient (68%).

EU added-value

Between 50 and 85% of the respondents think that H2020 provided an EU-added value in several aspects to a large and very large extent, especially in terms of the 'Size of the project budget' and 'Funding opportunities for specific topics'. To the least extent, it contributed to 'technical support provided'. 73% of the respondents answered that the project would not have been implemented without support from H2020.

3.3. Case studies

3.3.1. Case study 1: Sustainable soil management in agriculture

This case study illustrates how the topic of SSM has evolved from a "niche topic" towards one of highest relevance, i.e., at the level of a Mission in Horizon Europe. H2020 and its activities on SSM coherently continued the development which had been initiated in previous Work Programmes.

SSM is an important approach toward achieving a Green Transition and has the potential to contribute to various objectives including food security, environmental protection and carbon neutrality. The case study illustrates how H2020 has successfully contributed to promoting the topic in various member states and the mobilization of new stakeholder groups. Importantly, major achievements in this field do not follow the straight-forward pathways as often assumed for technical innovations but arise from the complex integration, harmonization and application and translation of existing knowledge into practice and the accompanying social and economic transformation processes. However, it also reveals, that these processes are only evolving slowly. Research and innovation will provide essential prerequisites but eventually, it will depend on the future legal framework for the effects to unfold.

3.3.2. Case study 2: Exploration of marine environments for industrial valorisation

This case study illustrates the impact of R&D funding mostly driven by socio-economic objectives – less by highly sustainability-driven research – which was characteristic of the first Work Programmes in Horizon 2020. Still, the exploitation of marine bioresources has the potential to address various SDGs.

FP funding is very important for the community to conduct R&D and to build strong consortia with partners across Europe, as in many Member States, national funding opportunities are rather low in this area. The topic of algae is rather broadly distributed across different programmes in the FP, but current developments are underway towards a more integrated approach.

Many projects achieved significant technical and economic progress, and in some projects, commercial exploitation started in or after the projects. However, well-known barriers such as upscaling, regulatory barriers for products on the market and a partial lack of consumer acceptance of new products from the sea impede market uptake. To address those barriers, the need for more interdisciplinary research including non-technical aspects became obvious. This can be addressed in line with the stronger explicit orientation towards Green Transition goals, which are addressed in the 2021 strategy towards a sustainable blue economy (including Algae Initiative) and the EU Mission "Restore our Ocean and Waters".

3.3.3. Case study 3: Improving food processes and industrial value chains

The present case study holds four major conclusions. First, it found no particular indications for grave concerns about how the FP delivered on its expectations, and thus the GT ambitions of the EC. Second, it highlights the importance of the subject. The list of events and developments outside the influence of the EU, which threaten its existence has increased ever more speedily. The Covid19 pandemic and the Ukraine crisis have only been the most recent crises to show the public the need to significantly ramp up the transition of the European food system towards a more sustainable, more resilient, and more just version of itself.

Third, due to their ad-hoc character, crises as the before-mentioned bear the danger of shifting political priorities in favour of existential, yet short-term, results. Those involved in developing further Horizon Europe are thus well advised to not lose sight of long-term GT goals like sustainability.

Fourth, the case study shows the complex nature of the subject, which covers sub-topics as diverse as e.g., sustainable packaging, alternative proteins, or efficient food logistics, and which must cater to the needs of a sector dominated by SMEs. This high complexity could diminish the effectiveness of EU R&I interventions as it may add to the watering-down tendency of extant institutional structures and dynamics, e.g., as it increases the circle of stakeholders to involve in the creation of project calls or exercises. Balancing diverging needs and interests without compromising on the sustainability motives of the field or the effectiveness of FP interventions thus constitutes another main challenge for decision-makers.

3.3.4. Case study 4: Sustainable and smart cities and communities

To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The work programs have established a portfolio of interventions in the smart and sustainable cities field which provided important foundations for progress towards EU policy priorities and objectives related to the green transition. Each of the pathways identified in this case study has contributed to this portfolio through a) novel integrated socio-technical solutions to the challenges associated with a green transition and b) important enabling conditions for expediting a green transition. Taken together, this portfolio provides a highly valuable basis that can be built on by Horizon Europe initiatives such as the Climate Neutral Cities Mission or the Partnership Driving Urban Transition (DUT).

Further strengthening the portfolio by developing systemic solutions which target the social and cultural conditions in which technology is embedded will be key. While the focus on higher TRL levels in the work programs was valuable it is important to also develop social or institutional innovations which cannot be based on TRL assessments alone.

Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact?

This case study identified a set of six factors for establishing an effective portfolio. These were present across all pathways.

1. <u>Focus on applied research:</u> This involved solutions with a higher TRL level as well as a stronger involvement of industry and private sector partners.

2. <u>Increased visibility through implementation:</u> Increased visibility of integrated solutions (pilots and demonstrations) reduced perceived risks (technological and/or financial) and improved learning on the practicalities of implementation.

3. <u>Focus on replication & upscaling</u>: The Leader-Follower logic enabled learning and exchange on the most relevant issues for replicating solutions and the involvement of the private sector / industry facilitated market integration thus upscaling.

4. <u>Integration of system solution</u>: The multi-system or nexus approaches directed attention to the interfaces of systems and sectors as well as the interfaces of social and technical solutions.

5. <u>Involvement of challenge owner and demand side</u>: Involving urban stakeholders, in particular local government and citizens, ensured the development of solutions that match their needs and improved ownership and thus uptake.

6. <u>Creating a "community of practice":</u> Community building across projects through e.g., the Smart Cities Marketplace enabled learning from each other and building on each other's results.

To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts?

Effective mechanisms for communication and dissemination support the capitalization on the investment made by the work programs. This case study identified several mechanisms, from project to program level, for improving communication & dissemination measures for impact. First, at the project level, coaching and capacity building of project stakeholders helped to improve the effectiveness of their project communication activities beyond traditional scientific channels and audiences. Second, communication and dissemination were effective in resolving tensions with stakeholders related to implementing solutions (e.g., tenants or interest groups) when used early in the project or even before it starts. Third, at the program level, communication and dissemination measures were particularly effective when they addressed the specific needs of a particular stakeholder group. Twinning and leader/follower pairing provide effective mechanisms for matching stakeholders with a shared interest, shared challenges or challenges owners with solution providers. On this basis, communication & dissemination measures were more targeted and thus effective in supporting the replication and upscaling of project results. Fourth, pursuing strategic partnerships with multiplier organisations who have established thematic networks (e.g., ERRIN, ICLEI) was beneficial to improve outreach. Such partnerships were also critical of national R&I stakeholders who are most effective in communicating through appropriate national channels further improving outreach.

To what extent has international cooperation and, more specifically, the association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme?

International cooperation with third countries was an important facet of the H2020 work programs and underlined the EU leadership role in tackling global challenges associated with the green transition. Cooperation with third countries was important to broaden research perspectives and explore new approaches and solutions to green transition challenges in the smart and sustainable cities field. Moreover, the investments in international cooperation exposed partners to the demands of international markets and provided first market entry points to them. This aspect of collaboration is reflected in the project participation of partners from third countries.

What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

With regards to EU added value, the work programs have created highly ambitious EU flagship initiatives which have demonstrated how overarching policy objectives can be operationalised. The effectiveness of these interventions, and thus EU added value, can be further leveraged by improving the alignment with national strategies and activities in terms of finding synergies, complementarities, or multiplier effects at the national, regional or city level to draw in additional stakeholders and tap into private and public sector funding streams. However, a discrepancy in EU added value between the EU 15 and EU 13 member states (see Annex, Quant results) is eminent which is rooted in historically grown structural differences of the national R&I systems between both groups. Although the participation of the EU13 Member States is high (they were involved in 92% of the projects), the EC contribution is still very low at 5.7% of the total contribution (in comparison, EU15 countries receive 85% of the total contribution with a funding of 461 million Euros). This innovation gap limits the potential to achieve EU-wide policy priorities associated with a green transition in the smart and sustainable cities field.

3.3.5. Case study 5: A single smart European electricity grid

The H2020 and partnership activities towards a single, smart European electricity grid are, in general, industry-dominated activities within the electricity sector. The calls identified as relevant for this case study are designed as a cross-cutting technology-oriented programme to establish a cyber-physical system in an incremental development approach. Private sector participants are dominating and public sector research as research and development partners are involved, but public bodies are virtually absent. An integrated technological and market-oriented approach is adopted covering a broad range of technology readiness levels (from TRL3 to TRL9). This is also reflected in the balance of research and innovation actions (RIAs) and innovation actions (IAs) in H2020 and the strong focus on stakeholder integration in partnership actions. Nevertheless, there may be a weakness in the sense that regulatory aspects and societal awareness and acceptance issues are not timely tackled or are even underrepresented.

It is acknowledged that smart grids are not a stated goal, but that their fundamental drivers are policy goals like climate protection and security of supply. So, the demand for smart grids comes from the widespread advent of intermittent renewable electricity production. H2020 has been successful with the provision of open tools and standards to avoid the dominance of private sector companies and to overcome barriers to the green transition related to incumbent sectoral structures. However, it was also made clear that the transformation of the electricity grid into a full-fledged smart grid is an endeavour for generations, and that the neglect of this fact may have led to disappointments when assessing the progress during the recent funding periods. Nevertheless, an additional push is seen in the current energy crisis, which could work as a turning point towards a massive increase in investment in smart grids to integrate renewables more quickly into the European electricity system.

3.3.6. Case study 6: Offshore wind

E.Q. 1.1 How relevant has the Framework Programme been in this area given the stakeholders' needs and considering the scientific, technological and/or socio-economic problems and issues identified at the time of its design and over time?

The Framework Programme interventions in the area of offshore wind have been relevant to the needs identified by stakeholders and the policy priorities identified at the time of its design. Many interventions were funded to lower the cost of offshore wind energy by increasing the efficiency of installation, operations and maintenance. Another area receiving significant attention was the development of new solutions for floating offshore wind.

The relevance of the Framework Programme has been supported by SET Plan bodies (ex. ETIP Wind) producing strategic research agendas based on recommendations from the wind energy expert community. Over the progression of the Framework Programme, innovation in floating offshore wind (including the development of a large 10MW Floating Offshore Wind Turbine) and system integration to deliver electricity onshore were given progressively more importance.

E.Q. 4.1. What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects leading to the achievement of the programme's objective(s) in this area?

The projects analysed as part of this case study delivered an increase in publicly available knowledge and evidence on a variety of innovations in offshore wind. Out of 32 projects, 21 are closed. From a technical point of view, these delivered new designs for offshore wind substructures, new systems for monitoring operations and identifying component failure, or servicing wind farms. Progress was made on meshed offshore networks and two enabling technologies were proven to operate safely at the required functionality. Amongst projects still ongoing, there is also a demonstration of a 12MW wind turbine.

Another key result of the projects was the upskilling and training of people who move between organisations and into industry, alongside the uptake of concepts and designs studied under Horizon 2020 projects by industry.

E.Q 4.2. Which internal or external factors have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact?

Among the factors that influenced project progress positively we find collaboration and cooperation. Collaboration of various parties within projects (such as companies, research institutes, interest groups, …) and across a representative geographic base enabled project success through the inclusion of diverse viewpoints which strengthened the offering developed. It also enabled the dissemination of results to relevant audiences across multiple countries, which generated interest in the project and take up of results after the project's end.

Among the factors hindering progress, stakeholders noted a certain inflexibility of the Framework Programme in the face of a rapidly changing offshore wind sector. It was mentioned that project objectives relating to cost reduction would become outdated fast in a context where the price of offshore wind was significantly dropping year-on-year and that funding was provided to projects working to outdated cost reduction objectives compared to market prices.

E.Q 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The Horizon 2020 Framework Programme work programmes have established a portfolio of interventions in the offshore wind field which provides important foundations for progress towards the European Union energy policy priorities under the European Green Deal and the Sustainable Development Goals (SDGs), namely SDG7 Affordable & Clean Energy and SDG13 Climate Action. Significant progress was made in offshore wind during the time of Horizon 2020 and offshore wind technology is now considered a mature technology.

Further progress in the two priority areas identified by offshore wind stakeholders in the two Lighthouse projects will be key, namely in floating offshore wind and system integration. Further R&D to reduce the cost balance of the plant (electrical kit substations, cables) will also be key for an overall reduction of the cost of offshore wind energy and its wider market take-up.

The Paris Agreement was a moment when the EU realised that renewables were no longer a "nice to have" and there was an urgency to accelerate climate action. Having operational offshore wind farms in the North Sea

EQ 4.5. To what extent has international cooperation and, more specifically, the association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme?

International cooperation played a considerable role in the portfolio with high project participation from the United Kingdom and Norway due to their activity in the offshore wind sector in the North Sea. However, within the EU the most active countries belonged to the EU-14 (Germany, Spain, the Netherlands, France and Denmark).

EQ 5.1. What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

The EU added value of the Framework Programme in the area of offshore wind seems to have been high for two aspects: a) cooperation and collaboration under common objectives b) supporting the diffusion of offshore wind in countries that were not traditionally active in this sector, making it a “whole European story”.

Regarding cooperation and collaboration, Horizon 2020 allowed projects to be carried out at the scale required, across different geographies and stakeholders, and for several years. International collaboration was key for the delivery of certain projects of the offshore wind portfolio, for example, a project working on offshore meshed grids which by its nature requires cross-border collaboration. The Framework Programme has provided an umbrella under which to coordinate research efforts towards common objectives and financial contribution was said to be a value-added to mobilise parties across countries, whilst other regional or international cooperation initiatives are more difficult because they do not provide funding for delivering R&I (for ex. under the International Energy Agency or the European Energy Research Alliance), or they focus principally on aligning political priorities (for ex. the North Seas Energy Cooperation).

Horizon 2020 played an important role in supporting the development of an offshore wind sector, in particular floating offshore in countries bordering the Atlantic Ocean and the Mediterranean Sea, also due to a requirement for projects to collaborate across an extensive geographical coverage.

3.3.7. Case study 7: Biofuels

E.Q 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

Most biofuels used today are first-generation which are those manufactured from food crops such as sugars and vegetable oils. The sustainability of first-generation biofuels is questionable as they compete with food crops and some of these fuels have a relatively low environmental advantage compared to traditional fossil fuels. The emerging food crisis and the Russian invasion of Ukraine made the use of energy crops that compete with feed and food crops for the production of bioethanol or biodiesel even more problematic. On the other hand, this conflict also underscores the need to accelerate the independence from fossil fuels where second-generation biofuels can play an important role.

Fuels with higher potential environmental benefits, particularly those associated with second-generation biofuels, exhibit lower cost-competitiveness which hinders market uptake and reduces their potential contributions to Green Transition policy objectives. This is particularly challenging given that aviation and heavy-duty transport as well as marine transport require higher energy densities that only some biofuels can provide so that they can fully contribute to the achievement of the 90% transport emissions reduction by 2050, outlined in the European Green Deal. Of note is the waste-to-to-fuel technology which produces energy-dense fuel, whilst also mitigating waste management issues and the negative environmental impacts of organic waste disposal.

There is no panacea or silver bullet biofuel technology solution that can by itself make big advancements towards a green transition and biofuels need to improve to be able to compete with fossil fuels in terms of costs or energy content. Consequently, exploration and exploitation of various fit-for-purpose biofuels in combination with the right political and market framework conditions will be crucial to make steps towards achieving the European Union policy priorities and rapid transitions in the transport sector.

E.Q 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact?

This case study identified 2 internal factors and 3 external factors that have influenced progress in the biofuel area. The following section starts with 2 positive internal factors followed by three negative external factors.

First, the internationalisation of research teams was an internal success factor which brought highly specialised expertise of different parts of the biofuel value chain together. This factor also concerns bringing expertise and experience from geographically different biofuel contexts together expediting knowledge co-production and knowledge transfer across Europe. Additionally, bringing research and industry stakeholders together helped to bridge the gap between research and implementation.

Second, given the long timeframes of developing new biofuel technology solutions and the time required to penetrate the market, another success factor was a strong commitment from an industrial stakeholder with strong expertise in biofuels. Projects with such a partner found it easier to overcome unexpected hurdles or delays during a project's lifetime. Additionally, strong partners were also crucial in providing the financial capacity to carry project results forward once a project reached its end.

Third, one of the negative external factors that limited investments and market uptake in biofuels was the frequent changes in the political framework conditions at the European as well as national levels. For example, updates to existing directives (e.g., Renewable Energy Directive II, see section 2.2) had a strong influence on biofuel R&I through the introduction of criteria that differentiated between the sustainability of biofuels and introduced more difficult to attain sustainability standards along the value chain. This prioritised the use of some biofuels over others (as well as a shift in emphasis on e-fuels and hydrogen, which is not part of this case study) and shifted the focus of R&I activities on ´favourable´ biofuels. These changing political priorities and the uncertainties that they induced were seen as creating unstable framework conditions for biofuels as well as fluctuating funding priorities for biofuel technologies. Taken together, these developments also created uncertainties for investors that damped investment interests. This is especially concerning given the large amounts of investment required for biofuel production capacities at scale. Overall, this negative external factor was, and still is, a major barrier to biofuel market uptake and integration, limiting the upscaling of project results.

Fourth, another negative external factor that hindered the progress of biofuels uptake is a lack of a commonly accepted methodology and accounting framework (e.g., life cycle assessment or Well-to-Wheel assessment) to reliably determine the costs and benefits of biofuels associated with their entire value chain (e.g., energy balance or greenhouse gas balance). Several methodologies with often fundamentally different assumptions were used by different projects and partners which can pose a risk in terms of using certain methods to interpret results favourably. The need for agreeing on the use of commonly accepted and standardised accounting and assessment methodologies was highlighted by interviewees who also pointed to the importance of co-developing such a methodology with industry stakeholders.

Fifth, another negative external factor is the negative public perception of biofuels. Whilst this is largely associated with first-generation biofuels and their competition with food crops and indirect land use changes (also known as a "food vs. fuel" debate) as well as media reports on potentially negative effects on engine performance and longevity, the negative image that emerged in the past influences public discourse and thus political debate on biofuels until today.

E.Q. 4.3: To what extent have dissemination, exploitation and communication measures enabled reaching these outcomes and impacts?

The communication and dissemination activities of projects were successful in promoting project activities and results. Also, the partnerships such as ETIP Bioenergy and EERA Bioenergy were undertaking communication and dissemination measures albeit on a portfolio level. This helped to better communicate the current state of the art on biofuels research and innovation developments from an overarching perspective thereby counteracting knowledge fragmentation and reducing redundancies between projects and the wider stakeholder community.

However, this case study also identified several measures that can help to improve communication, dissemination and exploitation in the future. For example, a stronger focus on communication and engagement measures with key stakeholder groups was identified as important (this could also be realised through dedicated communication & public engagement projects). Such interventions should focus on positive messaging about biofuels highlighting that today's biofuels must adhere to comprehensive sustainability criteria, thereby addressing some of the negative public perceptions about biofuels that are still present. Likewise, addressing stakeholders that are not as closely linked to the biofuel community (e.g., investors, financers) could be intensified because these players are critical for uptake and upscaling but are often not aware of the latest developments. The challenge to reach important stakeholder groups, however, is to convey targeted messages in an already overcrowded and fast-paced communication and information space. Making better use of social media and the delivery of key messages with the option to easily access further information was flagged as a promising strategy.

Some projects were also successful in establishing a “brand name” during their project duration that was well recognised by the biofuel community. It would be beneficial if projects could keep their name when they continue, even in a different consortium constellation or activity focus, as this would help to maintain the communicative benefits that come with a well-known and immediately recognisable project acronym.

Lastly, more open communication about failures and the sharing of difficulties and hindrances in the development of new biofuel technologies would be beneficial. Such information would need to be made available to relevant stakeholders only, but it would be beneficial for the biofuel community at large as it would also help to increase the investment and resource efficiency of projects.

EQ 4.5. To what extent has international cooperation and, more specifically, the association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme?

Knowledge and practice exchange as well as the testing of biofuel technologies in different contexts is critical to ensure the continuous progression of biofuels and their wider application. This importance is reflected in the portfolio analysed which had a 4.3% participation share of partners from third countries which is more than double the average share of SC3 third-country partner participation. Similarly, third-country partners also received a larger average amount of EC contribution in the biofuel’s portfolio compared to the average in SC3.

This strategic focus on third-country participation is particularly valuable with countries that have a long history of biofuel R&I and market integration. In such cases, third-country partners were complementing European expertise and provided insights into the requirements and dynamics of innovation systems that have a strong basis in biofuel research and implementation (e.g., bioethanol in Brazil).

EQ 5.1. What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

The EU-added value of the Framework Program is particularly pronounced in its success to establish a network of biofuels research and innovation experts. This is reflected in the institutionalisation of these networks like the European Technology and Innovation Platform (ETIP) Bioenergy or the European Energy Research Alliance (EERA) Bioenergy which did not only support knowledge transfer and exchange between researchers and practitioners but also pursued trans-national policy support activities (e.g. ETIP Bioenergy on policy support for market integration of biofuels) for improving the alignment between the funding and political framework conditions at EU and national level. These partnerships were successful in focusing transnational R&I activities on biofuel solutions and bringing research and industry stakeholders closer together creating a more direct link between research outputs and the application of new solutions under real-world conditions. They thereby helped in pooling knowledge and expertise and counteracting knowledge fragmentation.

Furthermore, the Framework Program was successful in establishing highly visible and well-recognised European projects which are internationally well-known. The Framework Program has thus helped to fund bigger and more prestigious projects which national R&I funding would not necessarily have been able to achieve by itself either in terms of financial capacity as well as the pooling of know-how and expertise. Pooling European expertise combined with providing the financial capacity was particularly important for projects that aimed for large-scale production capacities.

Additionally, the Framework Program was successful in establishing new research lines thereby setting the priorities for R&I activities in member states. This also helped to kickstart the formation of new research teams and to bring together experts from different parts of Europe.

An avenue to further improve the added value is to better link up to other EU and non-European funding opportunities that provide support along the entire innovation value chain and particularly when the project reaches its end and when promising results should be carried forward. While such complementary funding instruments are independent rather than fully integrated there is a growing understanding that better-suited financing options are required. One example in this regard is the innovation fund which provides capital for the development of large-scale industrial power plants and first-of-a-kind production plants.

Furthermore, this case study identified the need to better ´track´ projects results and outputs once a project has finished. This would help to better understand what support measures are required after a project has finished and it would provide important opportunities to make more informed adaptations to the work programs in the future.

3.3.8. Case study 8: Towards very-low emission and lightweight vessels

E.Q 4.1. What are the main results and (expected) outcomes and impacts of the projects supported in this area? Is the delivery of the projects' results altogether leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

Overall, the projects analysed have made a significant contribution to the H2020 measures to reduce pollutant and greenhouse gas emissions from shipping. The projects have delivered a wide range of new technological and material solutions, providing important findings for the transition to very low-emission and lightweight vessels. All analysed projects have successfully developed prototypes and shipboard demonstrators to demonstrate the feasibility of near-zero emissions shipping, thereby contributing to the objectives of the Framework program. While there does not appear to be a single measure that can be considered a problem solver, the combination of solutions such as new propulsion systems, new fuel types, and lightweight materials should result in significant energy efficiency improvements and environmental benefits. It would be therefore helpful to have some calls in the future where these solutions can be combined within a single project.

"I think if I could add something to my wish list, I would like to see some projects where we can combine solutions like that, like new propulsion systems, new types of fuel and lightweight. This is something because I think there are several enablers for reduction of emissions which combination could really lead to some spectacular achievements."- Project Beneficiary

Another key objective of the framework program was to develop solutions that are so close to market readiness that ship owners will consider these concepts in their future investments. All projects succeeded in significantly increasing the TRL, thus making the ships commercially viable with their new technological equipment and materials. In particular, certification procedures established in the E-Ferry project, for instance, can now be adapted, thus saving time and money and facilitating the introduction of new vessels. However, in some cases, it became apparent that further steps need to be taken to make certain technologies or materials marketable. In particular, it should be noted that a future demo case starting at a low TRL level will require more time for knowledge development to ensure practical implementation and to make the prototypes marketable. Some interviewees, therefore, emphasized the need for more knowledge-building with EU funding in smaller projects focused on a single problem first, before integrating it later into the whole system on higher TRL. Demonstrations that are conducted off-shore and start at a lower TRL are also very cost- and risk-intensive so shipyards or ship owners do not like to venture into demonstration projects that much unless the ships can be sold afterwards. To minimize risks for ship owners or other commercial users, the greening of ships should be even more focused on these commercial stakeholder groups and their needs. The uptake and interest of commercial stakeholders would also increase if there were new rules and regulations from the policy side. Therefore, new regulations would be urgently needed to achieve the goal of near-zero emissions shipping and to guarantee the acceptance to invest in new (technological) solutions and materials on board ships. In addition, due to the high complexity of the shipping sector, it is important that extensions are granted during the project period to find solutions to challenges and the minimization of risks. To make the ships particularly marketable and operable in real-world conditions, an infrastructure in ports must be established.

E.Q 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact?

In this case study, several success factors were identified that had a particular influence on the progress of the Framework Program interventions. In the following, the main success factors are briefly explained:

Project consortium and partners involved

A key success factor for all projects was that they had a heterogeneous consortium with industry partners such as shipyards or technology providers. It is important to work with commercial partners in the project right from the start so that the knowledge built up in the projects is more likely to be used in practice and lead to the acceptance and uptake of environmentally friendly vessels. Based on some interviews with project beneficiaries, it was furthermore helpful to split the role of the project coordinator between two organizations to increase the efficiency of the project work.

Cooperation with other EU projects

Cooperation with other EU projects aiming at similar solutions and facing similar challenges proved to be particularly valuable for the success of some projects.

Technology transfer

The aspect of technology transfer, e.g., from the aerospace industry, to learn from and adopt know-how, was seen as very fruitful.

Use of knowledge from previous projects

Using and building on knowledge from previous (EU) projects in the maritime field was crucial for all analysed projects to move forward faster in their respective projects.

Support from the EC

The support provided by the European Commission, and in particular by the project officers, was a factor contributing to the success of most of the analysed projects. Since the shipping sector is highly complex, major challenges can always arise, which then cause delays in the progress of the project. A project officer who understands this complexity and supports the project beneficiaries is therefore essential.

Higher TRL right from the very beginning to ensure a successful market entry

Currently, there is a large amount of technology push, along with a shift in market demand in the shipping sector. The decarbonization targets are more and more noticed in the market, where ship owners are beginning to invest in innovative technologies. To attract ship owners to projects, it can be sometimes important that a commercial benefit is evident as well as that the results of the projects are close to or ready for market uptake. From the analysis, it was found that a higher TRL at the very beginning of the project is quite often essential to ensure market readiness at the end of the project's lifetime.

In terms of potential obstacles, the following area stood out:

Regulation and Standards

The traditional way of building ships is still based on existing (international) regulations that need to be changed to commercially exploit the low-carbon and more energy-efficient ships and their technologies or materials. There are currently only preliminary new guidelines in place, which require further feedback from the international community before new regulations can be adopted. Certain markets, such as the ferry market, are changing faster than for example the cargo ship sector. In the ferry sector, the shift to electric and environmentally friendly operations is very much underway. However, governments often have an influence here, as ferry operators are part of the public transport sector. It becomes clear in this respect that politics strongly influences sustainable shipping efforts. In future projects, therefore, a combination of research and the development of requirements for standards or certification measures would be helpful. In this regard, it is also key that standard & certification organizations are involved in projects from the very beginning. Such organisations do not necessarily need to be involved as funded project partners, but rather as important network partners during the life of the project. In this way, the process of setting new standards, which follows its own rules and must take place outside the individual projects, can be accelerated and made more effective based on the knowledge base developed and the requirements arising from such R&D projects.

E.Q. 4.3: To what extent have dissemination, exploitation and communication measures enabled reaching these outcomes and impacts?

To demonstrate the benefits of the new vessels and/or their innovative technologies or materials and to foster their application, a vast number of dissemination activities have been carried out in the context of the projects. This includes scientific publications, the organization of events, the production of video material and the use of many other communication formats such as social media. Conferences and final events were very important for all respondents to communicate and disseminate their outcomes. However, COVID-19 negatively impacted some of these important communication and dissemination efforts. Many conferences had to be held online and could not be organised as large as originally planned. Cooperation in communication and dissemination activities with relevant networks such as the "ELAS network", "The EU Resource Efficiency Transition Platform" or the "Sustainable Shipping Technologies Forum" was highlighted as particularly valuable. Within those networks or platforms, public events can be organized, which in turn attract a lot of attention and reach broad stakeholder groups.

Project websites were also considered important to communicate and disseminate project outcomes. However, it was seen as a challenge to keep the project website alive after the end of the project period. To maintain the knowledge repository for the community, funding or a platform would have to be provided even after the project duration in order not to lose the knowledge and to make it easily accessible. One interviewee noted that current sites such as CORDIS are a little complex, especially for industry stakeholders, and that they often do not have the time to click through. This is why dedicated platforms are so important so that stakeholders from industry in particular can obtain information.

EQ 5.1: What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed? Could the stakeholders have implemented their research and innovation in another way, including through other national or regional support?

Funding opportunities for the development of very low-emission and lightweight vessels vary widely among member states. Most of the analysed projects could not have been realised with national funding due to their size, high TRL and budget. In particular, the building of demonstrators is very difficult to realise with national funds. EU projects also enabled beneficiaries to come into contact with companies or research organizations that would never have happened without the funding via the framework program. These collaborations inspire and stimulate new ways of thinking by opening up discussions with a wide range of partners from different countries. In addition, EU projects offer the opportunity to gain a very broad spectrum of experience and to expand one's network.

3.3.9. Case study 9: Zero emission aircraft

EQ 3.2. To what extent have the programme implementation processes in this area influenced the types of projects selected?

Implementation processes are following the standard for European calls and seem to be suitable to identify proposals that address new research areas and might lead to ground-breaking innovation. With the calls directed at breakthrough innovation very aspirational goals had been formulated which were not prescriptive. This led to many proposals being submitted covering a wide range of different areas and technologies. With more budget allocated to partnerships in H2020 than in FP7, a much higher level of competition was present than in the framework programmes before. Even very high-scoring proposals could not be retained due to the small size of the budget available. To be able to assess the diversity of different proposals it is essential to have diverse experts with complementary backgrounds – industrial as well as academic – to do the evaluation process.

One interviewee suggests publishing calls already at a draft stage to give as much time as possible for researchers to develop proposals. This would need to be agreed upon by all member states though, to provide a level playing field.

EQ 4.1. What are the main results and (expected) outcomes and impacts of the projects supported in this area? Is the delivery of the projects' results altogether leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

The expected impact of the analysed calls was to demonstrate the potential and mature the TRL of their research objects to prepare the ground for future highly innovative breakthrough products and services for European aviation significantly decreasing emissions and greening aviation as well as enhancing the competitiveness of the aviation industry.

Projects in the portfolio were able to generate significant performance improvements as well as increase the maturity of the involved technologies. Some of the projects can be considered pioneering and demonstrated the potential of for instance electric aviation and hydrogen in aviation. Projects have also contributed greatly to the development of new materials. All together projects' results are therefore leading to the achievement of the programme's objectives in this area.

Thus said, efforts are by far not sufficient to reach zero emissions in commercial aviation in the foreseeable future. While there are promising results for small aircraft segments and effort is directed at hydrogen aircraft with Clean Aviation Joint Undertaking, interviewees doubt that with the pace and route taken, zero-emission aircraft will be introduced by 2050 on a large scale. Hydrogen in aviation needs to be economically viable, and it will need to be a worldwide decision with the US, China and other large nations agreeing to work in the same direction because it is a worldwide infrastructure that needs adjusting.

E.Q 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact?

This case study identified a set of internal factors for establishing an effective portfolio that are influencing the progress of the interventions positively towards the intended impact.

<u>Building on previous project results</u>: Building on learnings from preceding projects and research in the area helps to further mature technologies towards higher TRL.

<u>Bringing excellence together</u>: Successful consortia manage to bring together the best researchers and industry experts in their respective fields.

<u>Integration of partners from other industries</u>: Aviation research benefits from experience gained in other industries, for example automotive. Research projects can open markets for new actors.

<u>Working with regulatory authorities</u>: Integrating regulatory authorities in the development of novel technologies early on helps reduce the time for certification.

Barriers to achieving impact could also be identified in the case study. Some of these can be considered as barriers internal to the Framework Programme:

Small budgets: Compared to investments in other areas the budget allocated to ground-breaking research is rather small. More results could be expected with larger investments.

Aviation as conservative industry: The aviation industry tends to rely on established networks where trust has already built up. This makes it difficult for new actors to enter the arena.

OEMs are risk averse: With safety being paramount OEMs tend to avoid taking risks. This hinders and slows down the uptake of new technologies.

Fewer Scientific Officers: A reduction in the number of Scientific Officers at the Commission left a resource as well as a competency gap.

There are also some challenges lying ahead that have the potential to become barriers to a green transition towards zero-emission aircraft or aviation in a broader sense.

Strategic steer: Interviewees point out that there should be a stronger steer from the Commission setting even more ambitious targets. An independent advisory board could play an important role, one that is rather independent from the industry and is composed of all relevant groups encompassing research, citizen representatives, and representatives from different transport modes as well as other industries. This might also put a higher emphasis on societal needs (e.g., noise reduction).

Keeping high standards of safety: One major accident with electric aviation and the whole project might be at risk.

Airport infrastructure: For hydrogen storage and possibly new aircraft configurations, some challenges might make it necessary to adapt airport infrastructure or infrastructure near airports. Investments needed are large and therefore reliable planning roadmaps are essential. This means far-reaching decisions need to be taken now.

Looking beyond the aircraft: Much higher reductions of greenhouse gas, as well as noise emissions, could be achieved from using alternative transport modes[19] – in other words: not flying at all – or flight operations (e.g., climate optimized flight routes). These options are not challenging from a technological point of view but challenging in implementation; they require political will.

Green energy supply: A general problem that does not only apply to aviation is the need for renewable energy to match the demand, which might even be rising.

EQ 4.3. To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts?

Dissemination measures are following a usual pattern for technology and innovation pathways with academic papers being very important. In addition, students are seen as an important stakeholder group with the future talent needed not only to push research but also in the production of new aircraft types. Projects were able to integrate students into their work.

Communication for the public needs to take into account that there might be objections to novel technologies. Producing short videos of some of the projects was seen as powerful to make results easily understandable to a wider public.

EQ 5.1. What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

The most important added value is that for some of the participants, research would not have been possible at all given the lack of national funding programmes dedicated to research in the field of aviation. Access to research infrastructure which would not be available on a national level is another aspect as well as engaging regulatory authorities is also easier at a European level.

With the recent changes in strategy, the EU is also changing its perspective: reducing greenhouse gas emissions becomes more important than the competitiveness of the industry. This serves as a stimulus for the industry to set more ambitious targets and invest in research.

EQ 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

In 2020, it is estimated that a share of 7.7 % of the total turnover of civil aeronautics was invested in R&D activities by private and public stakeholders[20.] Support from the EU institutions through EU-funded research programmes is essential in playing a leading role to develop the future of green technologies for civil aviation. With the sector's high investment in R&D, there is a contribution to SDG

9: Industry, Innovation and Infrastructure, as well as the focus on zero emission aircraft a contribution to SDG 12: Responsible Consumption and Production is given.

3.3.10. Case study 10: Sustainable and healthy urban transport

EQ4.1 What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results altogether leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

Considering the specific project portfolio, the results of these projects have contributed to the achievement of the programme´s objective in multiple ways. Across the project portfolio, the following overall contributions can be summarized:

Mobility services and technologies – The projects tested and demonstrated the potential of mobility solutions in a combination of new services and technologies, including more energy-efficient bus technologies, the widespread use of cargo bikes or the multi-modal integration of transport in port cities.

Digital tools – Several of the projects developed and/or tested specific digital solutions for urban transport challenges that were developed at close-to-market levels and tested by the participating cities. This allows cities to prepare for the take up of digital transport solutions in a different context (parking management, bus system, cycling infrastructure, tourism)

Legal and policy adaptations – Embedded in the wider frame of the CIVITAS initiative and the SUMPs, the projects efficiently developed specific guidelines and policy changes in their respective domain (cycling, bus systems, cargo bikes, tourist transport, port cities).

New knowledge stocks and capacities –A crucial result of the projects was the creation of knowledge on alternative, sustainable and healthy urban transport solutions as well as the build-up of capacities for taking up the solutions after the end of the project.

Community building – Creating a European community and critical mass for the transformation of transport systems through the integration of cities in the project and their connection with private and research organisations was a critical result of the project.

All the dimensions highlighted above-provided contributions to achieving the objectives of the programme in these areas and are embedded in the broader context of sustainable transport advances through the projects that include the institutionalisation of the SUMPs, the new standards for mobility management or increased recognition of the importance of cycling and walking in urban transport. As some of the projects are still not concluded, a final assessment of the achievement of objectives is not possible. However, the highlighted trends show a clear pathway towards creating the envisioned transformations, although the uptake and rollout are not always guaranteed. Here, better integration of H2020 (and Horizon Europe in the future) with other funding schemes (like e.g., ERDF programmes) could be a potential leverage as highlighted by some interviewees.

EQ4.2 Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and long term? Are there any factors that are more or less effective than others, and, if so, what lessons can be drawn from this?

Summarising the insights of the case study, several observations can be made that can contribute to compiling an effective project portfolio:

Promote a logical flow of investment – The H2020 programme has lived up to the objectives set out in the work programme, but to roll out the developed and tested solutions a better integration of different investment flows is needed. This means that transmission between the different layers of innovation and investment support portfolios on a European scale needs to be integrated to support and foster the take-up and roll-out of solutions.

Provide community platforms – The leverage of community building and networking (e.g., in the CIVITAS frame) was unanimously well regarded in the analysis and therefore should be continued also in future programmes.

Extend multi-stakeholder approaches –Related to community building the benefits of multi-stakeholder approaches have to be highlighted in the transport sector, bringing different stakeholders together at the same table. However, there needs to be a balance between focused community building and a broad multi-stakeholder approach in the light of the EU missions.

Focus on up-take of solutions – A key element that worked well is the testing of transport solutions and the build-up of capacities. However, the uptake of the tested solutions can only be secured if it is well embedded in investment logic (see above) and the policy commitments in cities and regions.

Balanced approach to flexibility – While some interviewees lauded the stringent management, implementation commitments and monitoring frames that grant agreements provide, others also pointed out that flexibility should be easier in the projects. This would encourage bottom-up experimentation that is riskier but also provides more potential for radical innovations.

Set and collect realistic indicators – A challenge for project beneficiaries is the assessment of their impact, especially as regards often hard-to-collect indicators for certain improvement in the context of transport in cities. Here a realistic assessment of data collection for certain indicators has to be part of the proposal writing and also needs to be emphasized in the evaluation process. Frameworks like the CIVITAS process evaluation provide a good starting point.

Foster synergetic approaches – Using synergies between different projects, funding schemes, actor constellations and networks were regarded as crucial contributions to achieving the holistic objectives of the societal missions. This should be reflected in the call and programme structure.

EQ4.3 To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts? What further actions are needed to maximise the impact of the Framework Programme interventions in this area?

Communication and dissemination measures can be important instruments for maximizing the impact of different projects. The portfolio of existing communication and dissemination measures applied by the project is very diverse (webinars, events, newsletters, videos, folders, best practice collections, local heroes showcasing etc.) and provides a rich pool for future projects. It became clear that the programme structure already demands a good knowledge and target plan for reaching the relevant stakeholders. Especially in the frame of public authorities, the C&D actions led to the creation of strong networks that can survive after the end of a specific project. Although the outreach to stakeholders generally worked well there were also areas of improvement flagged. Especially as regards the integration of certain domains of private industry (e.g., logistics, private transport operators, traditional transport industry) or the integration of small-scale and micro-innovation projects and the amplification of their solutions.

EQ 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The work programmes provided the basis for a project portfolio that contributed towards achieving the EU policy priorities and objectives related to green transition. Most notably, the programmes enabled the operationalisation of policy objectives in a concrete (urban) setting, bringing together key actors of transport and mobility. In doing so, the projects enabled cities to work on their concrete challenges and needs in the framework of transformative change necessary to achieve EU or international policy goals. The projects did so by a) testing and demonstrating the applicability of technical, service and process innovations and b) building communities of practice committed to green transition policy goals, mutually reinforcing efforts and creating a critical mass of change actors.

EQ4.5 To what extent has international cooperation and, more specifically, the association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme? Has international cooperation, and specifically association, increased the EU economic activity and jobs? (to be measured by category of Associated Countries and by Framework Programme part in order to fully assess its impact and inform future policy choices)

In the frame of the selected project portfolio, the relevance of international cooperation was minimal. As evident from the analysis of the participation numbers, only one third-country partner participated in the projects. In line with this fact, interview partners did not specifically highlight the relevance of international collaboration in the project. However, it was mentioned that an international embedding and a global view of best practices are crucial to moving transport transformations forward. In the case of the CityChangerCargoBike project, the cargo bike measures tested in the European project cities created so much attention on a global scale that after the project some of the measures were replicated in some Latin American countries via a project financed by FedEx. This can be regarded as a best practice example for exploiting and replicating project results outside of Europe. However, no examples of this transfer of solutions into the EU were found and therefore the value from the perspective of EU transport systems has to be considered minimal.

3.3.11. Case study 11: Shifting paradigms - mobility preferences and behaviour

EQ 4.1: What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results altogether leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

Regarding the climate targets in transport, a significant reduction of emissions can only be achieved by a significant reduction in car traffic and a shift of routes to other means of transport. With this in mind, it is crucial to look at all the instruments that could contribute to this necessary reduction. In this respect, the question was very proactive at the time. The research helped to look at different transport transformation tools and approaches, mostly for the first time in Europe-wide research.

The case study includes many different approaches dealing with the demand side of a more sustainable choice of mobility solutions. On the one hand, the preferences and possible incentives of users in different contexts and regions are investigated. On the other hand, the conditions that enable better transport choices are concretely improved through pilot projects in cities and regions.

All projects are contributing small pieces, all are needed in that way. It's certainly important that they build on one another. The early efforts that the Commission has been making in this field are much appreciated. It was important to look at different solutions, compare solutions and think about the benefits and pathways to scale it up.

For the more experienced or specialized project partners, the existing knowledge was confirmed and deepened (e.g., an overview of the state of car-sharing products in Europe). It was possible to do international comparative studies. The maturity of the markets and framework conditions of the different approaches varied greatly when the projects were launched in Europe. The differences have been elaborated on in the studies and contributed to a more realistic view of it.

Apart from the outcomes regarding research, several projects introduced new mobility solutions in pilot regions. The solutions mostly still exist in the cities and regions. They have been partially revised or adapted according to the experience from the pilot case studies but are still active. In some cases, the introduced or suggested pilot mobility solution or approach was an early starting point for still ongoing improvements in the city (e.g., redistribution of space between motorized and non-motorized transport modes). Another project mobilized, taught possible founders and supported social impact start-ups to address transport poverty and mobility solutions for vulnerable users as a profitable business case. Most of the start-ups (9 from 10) have grown after the project ended and survived until today.

EQ 4.2: Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact?

Success factors

International cooperation was necessary for the breadth of the pilot case studies in the projects to ensure a geographical mix and different sizes of regions and cities.

It was important that experienced project partners were represented in the team who knew the current state of knowledge. This enabled the newcomers to learn quickly. This was all the more true in cases where the market development was in some countries far ahead of the other member states (e.g., car sharing, MaaS).

In those projects that implemented concrete mobility options in pilot projects or via start-ups, the motivation in the team for social impact was very high.

Much experience with H2020 project management in detail with the consortium leader was an important success factor. A massive network and careful selection of partners are needed to establish an appropriate well-balanced consortium. The progress during the project should be continuously monitored. The ability of the coordinator to communicate with partners and appropriate time planning for tasks (e.g., data collection and app development) were also crucial.

Barriers

It is the task of the regional authorities to take action and make changes regarding mobility choices happen. In several pilot cases, the project was an early push. A challenge is also a changing political environment for projects in cities. It is problematic when political priorities change in municipal projects, then projects cannot be implemented as planned or disappear from the agenda (thus potential impact is hindered). During a MaaS project e.g., Luxemburg decided to offer public transport for free (early 2020). This meant that cross-border ticketing systems were no longer a high priority in this region. Parallel political developments and priorities, more important projects at the local level and resulting conflicts of interest can affect the success of projects.

In general, requirements and prerequisites for behaviour change and related communication should be considered. A stakeholder engagement consultation and sustainable mobility planning processes take time. Those conversations over the long term are an ongoing task to enable municipal decisions and real changes on the ground.

Technical experience with mobility options is needed at the city level. But the education of planners about cycling is still missing at universities, mostly planners are learning this on the job only.

In Horizon it is a big investment in developing a proposal and a challenging task. There are also many bureaucratic hurdles during the project period (e.g., exit or change in the legal form of partners) that can affect the progress of the project. This forms a barrier to participation. Projects also reported a lack of quick feedback on administrative or financial issues but also the content of the reports from project officers. Some projects lacked support for the project coordinator (which has no intervention options vis-à-vis partners) from the project officer, for instance, when a partner did not fulfil its commitments in an appropriate manner, quality or scope.

The common language English is also an issue for participation, especially for smaller cities.

In some projects, which have not finalized field work before 2020 the Corona crisis had a deep impact on pilots. The usage of public transport was considerably disturbed (lower number of users). This led partly to virtual pilots, which therefore could not fully realise their potential.

In some cases, there was no time in the project for more detailed scenarios for scaling up specific solutions (e.g., car sharing). This is one of the reasons why the direct outcome of such projects is implemented in a limited way.

There are no open calls in Horizon so far. If one would like to come up with good ideas, now the idea waits for the appropriate call and is then adapted. The calls in H2020 / Horizon Europe are created after a participatory process under the assumption that the good ideas are then known by the Commission. However, this does not cover everything. In addition, there is the "political influence" and overburdening with additional topics. Calls should not "piggyback" on so many political topics ("camel call" with humps). The coherence of the call and the submitted projects suffers from this.

A longer duration of projects (4-5 years) would be better because then one can allow more time for the mobility solutions to pass until the impact evaluation. Mobility patterns do not change that quickly. Participatory processes regarding the implementation of mobility solutions take also longer because one must build trust first. The project runtimes are too short for both (impact assessment after implementation of mobility solutions too early and necessary stakeholder participation before implementation).

E.Q. 4.3: To what extent have dissemination, exploitation and communication measures enabled the achievement of the outcomes and impacts?

There are strong incentives on the part of the Commission to communicate the results and messages to the outside world. This led to a standardisation of communication activities in all projects, mainly doing the same activities (e.g., websites, social media, newsletters, conferences). There are specialised communication professionals who do this work, almost through an assembly line approach. From today's perspective, the projects did everything necessary for dissemination and reached their target groups. The measures are different in terms of reach: conferences reach few target groups, but then intensively, in contrast, flyers reach many people without intensive interaction. However, most of the projects used standards but were not particularly creative. A lot of marketing effort went into appearances on social media, only to find a few followers there. Indicators for outreach are difficult to assess. Today, projects would also create more videos or podcasts according to their assessment. A special topic for most projects was to reach out to specific groups of users to participate in data collection or to test mobility solutions. Dissemination activities towards start-ups and the start-up ecosystem in some projects were very successful and can therefore be particularly highlighted.

The established profile on social media, as well as project websites, are no longer populated with content after the end of the project, therefore its long-term benefits are questionable. The result is a jumble of different project websites, which are difficult to access. The Cordis website with the project results has an outdated design, does not contain all results and is not sufficiently known even among project partners.

It was generally a problem, that the public relations work was required to be very directly linked to the production of the results. So, the results were produced, and in the same breath, it was already a question of how to communicate this and reach the public: What formats, what are the messages? Sometimes the transport scientists were overwhelmed with the task of quickly translating this into messages. It would have needed time to qualify the results, but there was too much time pressure. Thus, the communication was mainly based on what was already known. The messages were developed under the immediate impression of the results. But a little more processing would have been necessary. Thinking about the potential for improvement regarding mobility options, the main issue is that between the results and the appearance of the message, there is a bit of time for reflection. In the projects, more time should be set aside to convey that.

The physical distancing rules during the Corona crisis led to a switch of resources to online dissemination activities instead of printed matter or meetings in person; a larger audience was probably reached this way. For the projects under consideration, however, the fireworks of final conferences were impaired at the end of the project because public attention was also focused on other issues.

Learning courses for cities reached a good group (general context of mobility options for cities, modelling of expected results, political issues). It was considered more effective than general dissemination. Quick facts for policymakers are most important for dissemination. Online courses are now more important for a wider audience, as well as shorter bite-size inputs by reusing content. Reaching out to not involved cities, apart from a core group of already active cities, remains a challenge.

EQ 4.4: To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The results of the projects have been relevant to provide guidance on specific topics related to Sustainable Urban Mobility Planning (SUMP), as outlined by the European Commission's Urban Mobility Package[13] and described in detail in the European SUMP Guidelines[14] (second edition 2019). This mainly concerns the role of cycling and walking, MaaS and shared mobility.[15] Sustainable Urban Mobility Planning is a strategic and integrated approach to dealing with the complexity of urban transport. Its core goal is to improve accessibility and quality of life by achieving a shift towards sustainable mobility. SUMP advocates for fact-based decision-making guided by a long-term vision for sustainable mobility. As key components, this requires a thorough assessment of the current situation and future trends, a widely supported common vision with strategic objectives, and an integrated set of regulatory, promotional, financial, technical and infrastructure measures to deliver the objectives.

SDG 12.1 Sustainable Consumption and production patterns are relevant sustainable goals, especially regarding sustainable mobility. All projects contribute to this by implementing mobility solutions, supporting more sustainable choices and understanding user behaviour.

EQ 5.1. What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

For the topic of car sharing, cycling and walking as well as MaaS, the European Commission was an early pioneer in addressing this topic in a research programme. National sources would not have existed for most of the funded projects in this case study. The EU Commission was the only owner of public R&I funding, that was at that time at all interested in the questions raised. EU gave political backing and credibility for taking those topics seriously. The Commission's initiative has greatly accelerated the establishment of MaaS approaches.

Without H2020, most of the projects would not have been feasible. There is no substitute for international exchange, ensuring greater coverage of a European dimension of research. This is especially true for the diversity of case studies, mobility approaches and partners. It is important for social cohesion that Europe grows together through a network of people. An important added value was that European funding made larger projects (more regions, balance of partners) in European cooperation possible. National funding for the topics concerned was limited or not available at all.

From the perspective of this topic, the technology focus in Horizon is too one-sided, social innovation is only mentioned as a subordinate clause compared to technology development. On the other hand, the EU has an interest in commercialisation and technological world leadership. However, not all problems can be solved completely technologically.

3.3.12. Case study 12: Future transport - Mobility preferences and behaviour

EQ 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The European policy objective of bringing the death toll for all transport modes close to zero is still a way off. The calls and projects analysed for this case study provide a better understanding of human–machine interaction, contributed significantly to gaining an understanding of the role of behaviour in this interaction and have aimed at a holistic approach to including infrastructure, vehicles and people into potential solutions. This is a move in the right direction.

Human-vehicle interaction plays an important role in the development of autonomous vehicles. Here the research funded by the H2020 programme made clear that it is not just an issue of safer vehicles but also how drivers and pedestrians interact with the vehicle or how drivers judge risks, for example in the case of road–rail interaction at level crossings.

Safe infrastructure plays an important role in safer transport. Using technology to make infrastructure active, reporting weaknesses for repair combines the need for safety with efficient use of resources which is part of the Green Transition.

The research has further shown that there are nature-based solutions which can increase safety in hazardous conditions enabling a reduction of the environmental footprint of long-distance transport.

Further work will need to be done to predict human behaviour, especially at those points where people interact with machines or infrastructure. Taking into account cultural differences across Europe and learning from third countries as well as applying learning from Europe globally will be important contributors to advances across the globe in increased safety.

EQ 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact?

This case study identified two drivers of success for research in this area: one concerning the fields of research and another the research teams themselves. Within the sets of drivers of success, 6 specific factors can be identified:

- **Interdisciplinary research:** Understanding the links between behaviour and technology was a major driver of success for the projects involved in this study, i.e., understanding safety from the human factor perspective as well as the technology and bringing these together.
- **Bringing together users and providers of new technology for testing**: Testing in different cultural and socio-economic contexts matches the fact that there is a European Transport system consisting of many users with different backgrounds.
- **Nature-based and simple solutions:** Toolboxes to be used across many different countries need to be clear and simple, without being simplistic. Nature-based solutions, well-aligned with the objectives of the Green Transition, also help in hazardous situations in maritime navigation.
- **The innovation process is not uniform in this area:** The case study revealed that the innovation process for example in the area of autonomous driving is one of a (small) step-by-step development, with real-world testing in between which does not always lend itself to large project teams. Matching the number of project participants to the innovation process and enabling smaller teams may be more beneficial for some developments.
- **Decision makers sit at many different decision-making levels across the EU Member States**: Decisions which can lead to the take-up or neglect of R&I results range from local Government to national Government, public sector organisations and private entities. Dissemination of relevant results is therefore complex.
- **Highly motivated team and coordinator**: Having a good coordinator who allows people to work the way they want and need but ensures results are fed in when needed is key to success.

E.Q. 4.3: *To what extent have dissemination, exploitation and communication measures enabled reaching these outcomes and impacts?*

Several of the projects included in this case study had events planned for 2020 or 2021. These had to be moved online due to the COVID pandemic. These online conferences have proven more useful to disseminate the results of R&I than first anticipated, opening up dissemination to more stakeholders, especially in third countries.

Twitter and other social media platforms have also been useful dissemination tools.

Some projects identified the need for a list of "*real stakeholders*" from the Commission and national and regional governments that can make actual use of the results. In the field of transport safety, infrastructure plays an important role in safety. It is managed by national or local agencies with international agencies setting standards. Public organisations interact with private companies. The Commission could support the dissemination more across these different organisations by using its networks more.

Close cooperation with other projects also played an important role for projects in this case study. Using experts from sister projects or follow-up projects can ensure that research results are followed through into the future.

EQ 4.5. To what extent has international cooperation and, more specifically, the association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme?

Knowledge exchange and the testing of results in different cultural contexts are key to ensuring that the European Transport system works as one. Extending this to third countries has widened the viewpoint of several of the projects.

Cooperation with third-country partners was an important part of the work, however, it has also proven difficult. There is evidence that third-country partners, not being as well funded and dedicated to specific tasks under the EU projects, have not been able to commit as many resources as would have been necessary and beneficial. However, there has been evidence to the contrary, especially regarding the exchange of scientists in the early stages of their scientific careers.

EQ 5.1. What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

Partnerships make a difference. National research would not have the same impact due to a too narrow focus when many of the R&I questions are international.

Transport systems across the EU become more integrated, enabling the trade of goods as well as international travel. EU R&I in the area of safer transport enables this further integration. R&I across the EU compared to national R&I adds this additional perspective of integrated transport. Similarly for the global transport of goods across the Arctic where international approaches are essential to moving towards a safe green transition.

The calls and in particular the projects analysed have enabled identifying solutions that work in different social and cultural contexts. Including third countries in this process not only enables best practices being used elsewhere but also enables the European industry to match demands and requirements from elsewhere.

3.3.13. Case study 13: Adaptation for climate action

EQ 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The European policy objective of bringing the death toll for all transport modes close to zero is still a way off. The calls and projects analysed for this case study provide a better understanding of human–machine interaction, contributed significantly to gaining an understanding of the role of behaviour in this interaction and have aimed at a holistic approach to including infrastructure, vehicles and people into potential solutions. This is a move in the right direction.

Human-vehicle interaction plays an important role in the development of autonomous vehicles. Here the research funded by the H2020 programme made clear that it is not just an issue of safer vehicles but also how drivers and pedestrians interact with the vehicle or how drivers judge risks, for example in the case of road–rail interaction at level crossings.

Safe infrastructure plays an important role in safer transport. Using technology to make infrastructure active, reporting weaknesses for repair combines the need for safety with efficient use of resources which is part of the Green Transition.

The research has further shown that there are nature-based solutions which can increase safety in hazardous conditions enabling a reduction of the environmental footprint of long-distance transport.

Further work will need to be done to predict human behaviour, especially at those points where people interact with machines or infrastructure. Taking into account cultural differences across Europe and learning from third countries as well as applying learning from Europe globally will be important contributors to advances across the globe in increased safety.

EQ 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact?

This case study identified two drivers of success for research in this area: one concerning the fields of research and another the research teams themselves. Within the sets of drivers of success, 6 specific factors can be identified:

- **Interdisciplinary research:** Understanding the links between behaviour and technology was a major driver of success for the projects involved in this study, i.e., understanding safety from the human factor perspective as well as the technology and bringing these together.
- **Bringing together users and providers of new technology for testing**: Testing in different cultural and socio-economic contexts matches the fact that there is a European Transport system consisting of many users with different backgrounds.
- **Nature-based and simple solutions:** Toolboxes to be used across many different countries need to be clear and simple, without being simplistic. Nature-based solutions, well-aligned with the objectives of the Green Transition, also help in hazardous situations in maritime navigation.
- **The innovation process is not uniform in this area:** The case study revealed that the innovation process for example in the area of autonomous driving is one of a (small) step-by-step development, with real-world testing in between which does not always lend itself to large project teams. Matching the number of project participants to the innovation process and enabling smaller teams may be more beneficial for some developments.
- **Decision makers sit at many different decision-making levels across the EU Member States**: Decisions which can lead to the take-up or neglect of R&I results range from local Government to national Government, public sector organisations and private entities. Dissemination of relevant results is therefore complex.
- **Highly motivated team and coordinator**: Having a good coordinator who allows people to work the way they want and need but ensures results are fed in when needed is key to success.

E.Q. 4.3: ***To what extent have dissemination, exploitation and communication measures enabled reaching these outcomes and impacts?***

Several of the projects included in this case study had events planned for 2020 or 2021. These had to be moved online due to the COVID pandemic. These online conferences have proven more useful to disseminate the results of R&I than first anticipated, opening up dissemination to more stakeholders, especially in third countries.

Twitter and other social media platforms have also been useful dissemination tools.

Some projects identified the need for a list of "*real stakeholders*" from the Commission and national and regional governments that can make actual use of the results. In the field of transport safety infrastructure plays an important role in safety. It is managed by national or local agencies with international agencies setting standards. Public organisations interact with private companies. The Commission could support the dissemination more across these different organisations by using its networks more.

Close cooperation with other projects also played an important role for projects in this case study. Using experts from sister projects or follow-up projects can ensure that research results are followed through into the future.

EQ 4.5. To what extent has international cooperation and, more specifically, the association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme?

Knowledge exchange and the testing of results in different cultural contexts are key to ensuring that the European Transport system works as one. Extending this to third countries has widened the viewpoint of several of the projects.

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EQ 5.1. What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

Partnerships make a difference. National research would not have the same impact because of a too-narrow focus when many of the R&I questions are international.

Transport systems across the EU become more integrated, enabling the trade of goods as well as international travel. EU R&I in the area of safer transport enables this further integration. R&I across the EU compared to national R&I adds this additional perspective of integrated transport. Similarly for the global transport of goods across the Arctic where international approaches are essential to moving towards a safe green transition.

The calls and in particular the projects analysed have enabled identifying solutions that work in different social and cultural contexts. Including third countries in this process not only enables best practices being used elsewhere but also enables the European industry to match demands and requirements from elsewhere.

3.3.14. Case study 14: Nature-based-solutions – innovation in support of natural resources and ecosystems

EQ 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and long term? Are there any factors that are more or less effective than others, and, if so, what lessons can be drawn from this?

The work programs have established a portfolio of interventions in the NBS field which provided important foundations for progress towards EU policy priorities and objectives related to the green transition.

Each of the pathways identified in this case study has contributed to this portfolio by a) establishing the relevant networks and fostering interdisciplinary collaboration, and b) enabling innovative decision support and integrated eco-socio-technical solutions to the challenges associated with a predominantly urban green transition. Taken together, this portfolio provides a valuable basis to be built on by Horizon Europe initiatives such as the Climate Mission or the Partnership Driving Urban Transition (DUT).

Further strengthening the portfolio by developing systemic solutions which target the monitoring, governance, legal, financing and sociocultural conditions in which NBS is locally embedded will be key, as well as finding common denominators and demonstrators for upscaling. While the selective focus on learning and connection platforms with regard to three main ecosystems (urban, coastal and freshwater) in the work programs was valuable it is important to also develop social or institutional innovations which cannot be based on exchange alone but would require the development of additional FP instruments (and beyond) and suggest structural changes regarding the EC RTD governance and DG collaboration.

EQ. 4.1 What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results altogether leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

According to our interviewed experts, the outcome (as far as available as of now) and impact of projects have been overwhelmingly positive. First, inter and transdisciplinary R&I has been fostered, essential community network and decision support platforms were/are established and respective databases/tools as well. Projects have effectively rendered proof that NBS have the potential to achieve what they are supposed to, at least in the urban context and with

regard to the participation of public administrations and other governance actors. The thematic transition from NBS towards NBS with a clear adaptation focus (termed "NBaS" by Al Sayah, Versini, and Schertzer (2022) has been linked to the Covid-10 pandemic and the impact of climate change in Europe. However, there are several voids to be explored further: the almost complete absence of NBS in rural contexts (especially agriculture and food supply, only occurring in SC3), the enormous focus of NbS project within the core countries (EU13 virtually absent in the projects), but also on research (in particular, nature, life and tech-sciences) on the long-term monitoring of implementation related effects of NBS and the interdependencies across micro-ecosystems of such impact. Overall, while some DG representatives claim to have sufficient knowledge established in H2020 to now move to broad implementation in Horizon Europe, the scientific community is less enthusiastic and asks for more research (on impact and cascade effects) with a duration of at least 5 to 7 years.

E.Q. 4.3: ***To what extent have dissemination, exploitation and communication measures enabled reaching these outcomes and impacts?***

Effective mechanisms for communication and dissemination support the capitalization on the investment made by the work programs. This case study gathered evidence on several actions, from project to program level, for improving communication & dissemination measures for impact. First, at the project level, the learning and capacity-building of project stakeholders helped to improve the effectiveness of their project communication activities beyond traditional scientific channels and audiences. According to Science Metrix bibliometric data, open access publishing is at a 79.5% rate, which is close to the climate case within SC5 (84.1%). Regarding concrete channels within the three SC5 cases, outreach via news and Facebook has been more effective than Twitter and generally fared better than in the Circular Economy case. Second, at the program level, communication and dissemination measures were particularly effective when they addressed the specific needs of a particular stakeholder group. However, to do so, sustained project monitoring at the program level is key and could not always be ensured. Fostering twinning and leader/follower pairing could provide effective mechanisms for matching stakeholders with shared interests, shared challenges or challenges owners with solution providers. On this basis communication & dissemination measures were more targeted and thus effective in supporting the mutual information, learning and decision support availability of project results. Fourth, pursuing strategic partnerships with multiplier organisations that have established thematic networks at the international level (e.g., IUCN, UNEP, IPBES, Sendai) was beneficial to improve outreach. Such partnerships are also critical with regard to national R&I stakeholders who are most effective in communicating through appropriate national channels further improving outreach.

EQ 4.5. To what extent has international cooperation and, more specifically, the association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme?

Overall, with regard to SC5, international cooperation with third countries should have been an important facet in the relevant H2020 work programs and underlined the EU leadership role in tackling global challenges associated with the triple nature, climate and biodiversity crises. Funded research underscores the need for continuously fostered cooperation with third countries in the field of NBS and particularly NBS focused on adaptation, important to broaden research perspectives and to mutually learn from new approaches and solutions to green transition challenges in the climate adaptation and resilience field linked to NBS. This was confirmed across all interviews but is also reflected by 21 third-country project participations. Moreover, investments in international cooperation can expose partners to the demands of international markets and provide first market entry points to them at a larger scale. In this sense, international cooperation under H2020 has received good attention (with some exceptions, particularly in Eastern Europe), explicable perhaps by first developing and testing a proper NBS approach by leading consortia in the EU.

EQ 5.1. What is the EU-added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

With regards to EU added value, the work programs have created highly ambitious EU flagship initiatives which have demonstrated how overarching policy objectives can be operationalized and turned into concrete decision support tools. The effectiveness of these interventions, and thus EU added value, can be further leveraged by improving the alignment with national and sub-national strategies and activities in terms of finding synergies, complementarities, or multiplier effects at national, regional or city level to draw in additional stakeholders and tap into private and public sector funding streams.

However, an enormous discrepancy in EU added value between the EU 15 and EU 13 member states is eminent which is partly rooted in historically grown structural differences of the national R&I systems between both groups, but in the field of NBS particularly striking, related to diverging policy priorities, especially since 2018. The participation of the EU13 Member States is very low (they were involved in 10.1% of the projects) and accordingly the EC contribution is also very low at 8.1% to the total contribution (in comparison, EU14 countries receive 68.1% of the total contribution with a funding of 741 million Euro). This innovation gap limits the potential to achieve EU-wide policy priorities associated with a green transition based on NBS actions.

3.3.15. Case study 15: A sustainable, resource efficient circular economy - innovation in support of sustainable supply and use of raw materials

The Horizon 2020 FP has put Circular Economy on the map as an important area for research. The first calls for Circular Economy research started in 2014, with Circular Economy mainly being framed as a waste-related challenge. There was no overarching Circular Economy mission yet that framed the FP calls. Throughout the FP, the scope of Circular Economy-related calls changed while new Circular Economy policies were formulated. The focus shifted to making value chains more circular from the beginning to the end, as well as to more material integration on industrial sites. The analysis shows that while Horizon 2020 was very valuable to make the first steps to more research on Circular Economy, there are still next steps to be taken for the next FP(s): to take a more holistic view, to focus even more on how Circular Economy thinking can be applied to specific sectors, and to contribute more to the newly created Circular Economy policies.

The coherency of the FP with other policies could be improved: both with Circular Economy-related policies, and with sector-specific policies that are still based on linear economic models. To increase coherence with Circular Economy-related policies, a main suggestion from our analysis is that the communication between DG RTD and DG ENV should be improved.

The results of the H2020 projects are generally positive: they have led to more insights into Circular Economy opportunities on the material level, city level and value-chain level. On the material level, new insights have been discovered on the recyclability of materials. At a city level, Horizon 2020 projects supported the exchange of best practices. At a value-chain level, more collaboration for circular approaches has been established within EU-wide value chains. An external factor that was necessary for this success was the involvement of the private sector. project portfolio analysis shows a relatively high involvement of private sector organisations in the Circular Economy-H2020 projects. This is necessary, given that many of the value chains that need to make the transition to a more circular model are already established value chains. These established private organisations need to be convinced to change their business models, so their involvement is critical. An internal factor that could be improved is to make a proper gap analysis and policy-coherence analysis, to show what Circular Economy research is needed. Dissemination and Communication of the project results happened mainly at the end-of-project events with the executive agency RIA, which are seen as good opportunities to showcase the projects. A point of improvement here is that more stakeholders could join these events, especially private organisations that could use the results in their business, and policymakers as their involvement in the events could help improve policy coherence with the H2020 FP. The results also contributed to the Sustainable Development Goals, in particular SDG 12, especially as the last H2020 calls in 2018-2020 explicitly mentioned this SDG in the calls.

International cooperation within the EU has helped the H2020 projects to be successful. Considering that many of the value chains in which circular approaches are most needed are EU-wide, or even global, an international approach is needed to make a difference in achieving the environmental objectives of the FP. The analysis did not show that association with third countries is crucial. The steps towards Circular Economy approaches in these calls were mainly focused on within-EU value chains. The EU-added value of the FP is high in the Circular Economy area, considering that many of the value chains in which circular approaches are most needed are EU-wide and therefore benefit from a holistic EU-wide approach. For more local / regional-level Circular Economy approaches, such as industrial-site-specific ecosystems, the EU-added value lies in the exchange of best practices between different sites. The excellence-based approach of H2020 was also helpful: this way, the best universities and experts in the EU work on the Circular Economy calls.

3.4. International benchmarking

As a result of the international benchmarking, the following good practices were identified for each of the organizations. Annex VIII provides a detailed overview of the results of the analysis.

3.4.1. KLIMAFORSK (NO)

KLIMAFORSK has a clear organisational set-up laid out in three predetermined annual themes covered on a rolling basis. This provides clarity for the research groups on what to expect. At the same time, there is room to apply for more innovative projects outside the predetermined topics through a specific call, which leaves room for bold and novel ideas. KLIMAFORSK keeps its strategic priorities up-to-date through its programme board and annual discussions on research needs with relevant policymakers. KLIMAFORSK has structural objectives to keep the focus on promoting the general non-typical and societal aspects of its research. Finally, KLIMAFORSK focuses on international collaboration, which helps their research disseminate and supports their reputation in the field.

3.4.2. NSF (US)

During the proposal review process at the NSF, external reviewers are included to assess the proposals. The NSF intends to include a broad representation of multiple stakeholders in the review process (including from diverse types of organizations). Similarly, proposers can also suggest reviewers. Both aspects help the NSF to keep up-to-date with use-inspired or upcoming research opportunities. The calls for proposals are also very much standardised, easy to find and straightforward in terms of readability. The NSF can be lenient concerning the disbursement of funding and the duration of a project once the grant is awarded to a proposal. This was highly valued by interviewees because not all projects fit into a standard model. Especially in the context of the inter- and multidisciplinary projects that are needed to research the complex challenges that encompass climate change, the impacts of climate change and adaptation measures, it is very valuable that funders are flexible and interact with the researchers to understand their needs. Finally, advisory committees play an active role in providing advice and recommendations to NSF Directorates and Offices. The members of these advisory committees come from a wide range of stakeholders, including academia, the private sector and policymakers. They play a vital role in keeping the research on the scientific and technological frontier, through discussions on the disciplinary needs and opportunities, the role of research and education, integrations of novel methods and other disciplines and the policy implications.

3.4.3. ACRP (AT)

Proposals are reviewed externally by three international reviewers and can be invited to improve and resubmit, which has been particularly appreciated by researchers, steering board members and policy-makers alike. Similarly, to the NSF, proposers are asked to suggest reviewers who, however, will be included in a well-maintained database and employed only in the upcoming year's review period. Steering board members rotate based on several years of service; Staffing of the Steering board involves thinking about including criteria of excellence, research applicability and policy relevance. Differentiated calls and funding instruments, including a specific call for quick results relevant to national climate-related policy-making, have proven to be successful.

3.4.4. FONA (DE)

The German case is a uniquely situated framework programme with self-claims to world leadership in terms of sustainability transition and research (thus going beyond climate action and research). Best practices refer 1. to an extremely efficient review and project execution process, 2. close ties to the research (academic and non-academic) and policy community, as well as through its instruments, 3. efficiently tackling infrastructure and large-scale transition projects. This holds especially true with regard to R&I (inclusion of the private sector (starting with FONA 2), transforming university infrastructure, curricula and departments, various university-related and non-academic research group establishments and the overall inclusion of an interdisciplinary and even transdisciplinary focus in research and R&I.

3.5. Policy workshop

A policy workshop was held on January 12 with 26 representatives from EC and MS. The objectives of the meeting were to share the key study findings, and to discuss, in small groups, how to enhance the contribution to the green transition, with three questions:

- What is the role of R&I to support the green transition?
- How has Horizon 2020 contributed to the green transition?
- How to boost the Green Transition in the future R&I programmes in Europe?

Overview of main discussions of **group 1**:

- Contribution of R&I to the Green Transition
  - Integration of different dimensions and time frames: This includes the need to balance long and short-term solutions, scaling up novel solutions which have been developed, balancing and coordination of goals (i.e., to solve potential conflicts between economic, social and environmental goals), and the consideration of the whole value chains (including autonomy aspects)
  - Early consideration and independent, holistic assessment of benefits and impacts, taking into account also indirect negative effects (e.g., high energy requirements resulting from digitalization) and potential mitigation approaches
  - Support the process of broadening the understanding of innovation beyond technological innovation
  - Support systemic change: socio-economic change and provide further indicators/metrics for difficult-to-quantify socio-economic goals like the quality of life)
- Green Transition in H2020
  - In the context of this evaluation, changing perspectives on the green transition must be kept in mind and how change happens in different contexts
  - Further need for improvements on multi-stakeholder integration: need to analyse which level/which instruments (i.e., FP, partnerships) provide the largest added value, enable learnings on best practices from existing programmes (both linked to the green transition but also other programme parts of H2020)
  - Use of successful examples as showcases for the coordination of European and national stakeholders

- Recommendations to boost the Green Transition

    - Effective coordination of R&I and sectoral policies is seen as the key. Therefore, efforts to align sectoral policies and R&I are crucial. Cases, where R&I has successfully influenced policies, should be analysed in detail to deduce recommendations

Overview of main discussions of group 2:

- Contribution of R&I to the Green Transition

    - The role of R&I to support the Green Transition is to make the European Green Deal the overriding objective of R&I programmes; align R&I objectives with key policy environmental and climate goals across different programmes and instruments; and set a clear framework for monitoring (specific objectives, indicators) of HE contribution to the Green Deal. R&I in itself cannot enact socio-ecological, so better coordination with sectorial policies is needed.

    - In addition to climate, R&I should support the EU's environmental goals: zero pollution, circular economy and biodiversity. Important to support R&I on non-tech solutions, e.g., behavioural change.

- Green Transition in H2020

    - Fostering collaboration between different actors: academia, industry, primary producers, consumer organizations, etc. has worked well in H2020.

    - Improvements should be made regarding greater participation of research actors outside the big 5 countries; simplification of procedures to help smaller organisations / non-traditional research actors to participate (environmental NGOs, local authorities).

- How to boost the Green Transition in the future R&I programmes in Europe?

    - Future R&I programmes should explore synergies with other EU funding instruments (structural funds, ERBD, etc) and support countries and regions with lower R&I capacity and participation in R&I programmes; reach regional manufacturing independence from threatening geopolitical factors.

    - Within partnerships a common approach for topics/monitoring should be introduced to the calls' deployment of the R&D solutions; attract more Member States to contribute and create synergies with national programmes.

    - Create accelerators that are mainly focused on ESG[23] agenda. Repetition of actions should be avoided; revise solutions, tools, and knowledge that has been produced and can be ready to use or validate before funding new programmes.

Overview of main discussions of group 3:

- Contribution of R&I to the Green Transition:

    - Able to combine vernacular and new knowledge with place-based and tailored context.

    - Supports change in mindsets and behaviour

    - R&I as a "policy of opportunity": long-term effects vs. market readiness approaches.

[23] Environment, Social, Governance

- Support systemic change: socio-economic change and provide further indicators/metrics for difficult-to-quantify socio-economic and governance goals like quality of life.

- Green Transition in H2020
  - Great support to integrate solutions with transdisciplinary, participatory and multilevel approaches
  - Opportunity to support new and smaller Member States, perhaps creating a differentiated, low access line of (lower budget) funding for them to enable capacity-building in the mid to long-term.

- How to boost the Green Transition in the future R&I programmes in Europe?
  - Better alignment and coordination between regional and national activities in general, but also taking a more proactive approach in this regard for shaping the Green Transition.
  - Include both research and awareness of socio-cultural aspects of quality of life and experience (beyond functionality, combining new and vernacular forms of knowledge).
  - More of a controlled systems / holistic approach, not just "serendipity" of parallel measures and actions in a combined view.
  - Stronger support to small-scale projects to engage smaller actors, and more, even explicit, focus on social, and not only technical innovations.
  - Improve knowledge sharing, networking and wide participation across similar projects, ends and goals, this should include de call dissemination system which needs improvement. Also, the role of SMEs needs to be strengthened, as well as the dialogue with national research entities and partners.

4. Conclusion

This synopsis report presents the methodology, data and key results from the consultation undertaken as part of the evaluation.

The consultation included:

- A survey with 771 complete responses from stakeholder group 'Representatives of applicants, beneficiaries, partnerships'.
- Targeted consultation, with 202 interviews
- Case analysis, including 15 case studies, 10 partnership studies and 4 benchmark cases.
- One policy workshop with 26 participants (excl. project team members).

ANNEX VII: SURVEY RESULTS

1. Introduction

This report aims to analyse the survey carried out between July and September 2022. Basic information about the survey and the process is provided below as well as the profile of the respondents.

The analysis is organised on one hand by societal challenge for relevance, effectiveness and EU added value and for all societal challenges together for the evaluation criteria efficiency.

The analysis is also organised by topics within each evaluation criteria and it includes the respective graphs. The captions of the graphs are identical to the questions of the survey. Besides an in-depth analysis of topics and questions, the authors of the report attempt to provide summaries whenever possible.

1.1. About the survey

The survey is one of the main information tools within the evaluation. It was designed during the inception phase and was further enriched and developed with gateways, to take into account various factors:

- The development of the intervention logics. Specific response items for each societal challenge were added to the questionnaire, notably to cover the effectiveness part (results, impacts). Four questionnaires will be implemented on the survey platform, to cover each societal challenge within the scope of this evaluation.
- The development of an additional section related to the transition process.
- The already available information (e.g. project ID, project name, type of project), to avoid asking unnecessary questions to beneficiaries.
- An alignment of questions with a survey launched earlier this year under a similar parallel H2020 evaluation, of which members of our consortium are part. By aligning most of the questions and response items on the efficiency part, it will allow the EC to (i) compare results across evaluations / societal challenges and (ii) enlarge the pool of respondents.

1.2. Process

The updated survey questionnaire was shared with the Commission on June 7th 2022 for feedback. The contact details were received by the consortium on June 7th. The Commission provided 47,883 emails in total, which included 31,763 distinct emails. The contact details covered 1,479 distinct projects. The experience from a similar parallel evaluation shows that this database could contain a significant number of inaccurate email addresses due to staff turnover and the collection date of the address, which was in 2014 for some. Due to the bounce rate and survey platform policies, it could have triggered some delays in inviting participants to respond to the questionnaire, and the consortium proceeded to execute a preliminary email check.

These emails originate from 7,504 distinct organisations according to the PACO PIC number. The numbers of participants and organisations vary widely from one project to another, ranging from 88 distinct organisations and 353 distinct participants to 1 organisation and 1 participant. Out of the 1,479 projects, 113 had the same number of organisations and participants. For 1,366 projects the contact details provided contained more than one representative per organisation. 6,144 emails belong to participants that were involved in several projects, ranging from 2 to 46 projects. 25,619 emails are linked to a unique project. These overlaps were dealt with by removing only duplicates of both the project and the respondent's name. Stakeholders were invited to respond only once, for the most advanced project.

1.3. Number of the respondents

In total, the survey received a total of 1333 entries, of which 771 of the respondents reached the end of the survey. As no question was compulsory, the number of responses varies from one question to another. Further, some questions are related to gateways, depending on previous answers. The number of observations per question/item is thus presented in each graph.

For the sake of margin error calculation, if we retain only the 771 complete responses at the highest confidence level (99%), this represents a 5% margin of error. Any share response (κ) will then have a confidence interval of [κ-5%,κ+5%]. At a lower confidence interval (95%) this margin of error reduces to 3%.

If you wish to retain the highest number of responses (1333) for the sake of margin of error calculation, then both margins would be equal to 3%.

The distribution of respondents in terms of Societal Challenges is illustrated in Figure 48. 33% of the respondents were part of SC3, 27% of SC2, 24% of SC4, and 16% of SC5. To understand if the survey respondents are representative of H2020, the survey data was benchmarked with the data on the overall H2020 structure, to see whether there are major differences between the two. In general, for H2020, there is a higher percentage (38%) of projects from SC4, and a lower percentage from SC2 (18%). The other Societal Challenges show little difference.

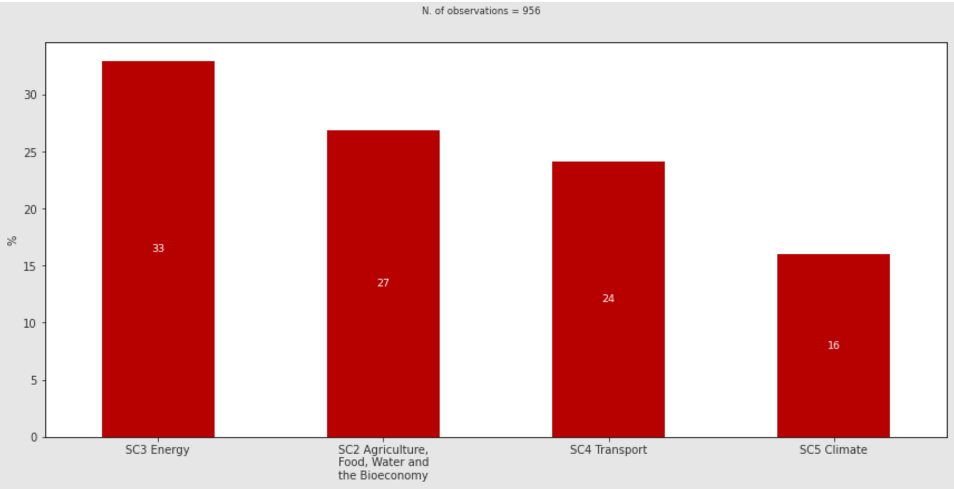


Figure 48. Distribution of responses per Societal Challenge.

The distribution of responses per country is shown in Figure 49. It is clear that by far the most (14%) of the responses come from Germany, followed by Spain (11%) and Italy (11%). Benchmarking the survey data with the data on the overall H2020 structure, showed a similar order of representation of countries, although the percentages overall showed smaller differences.

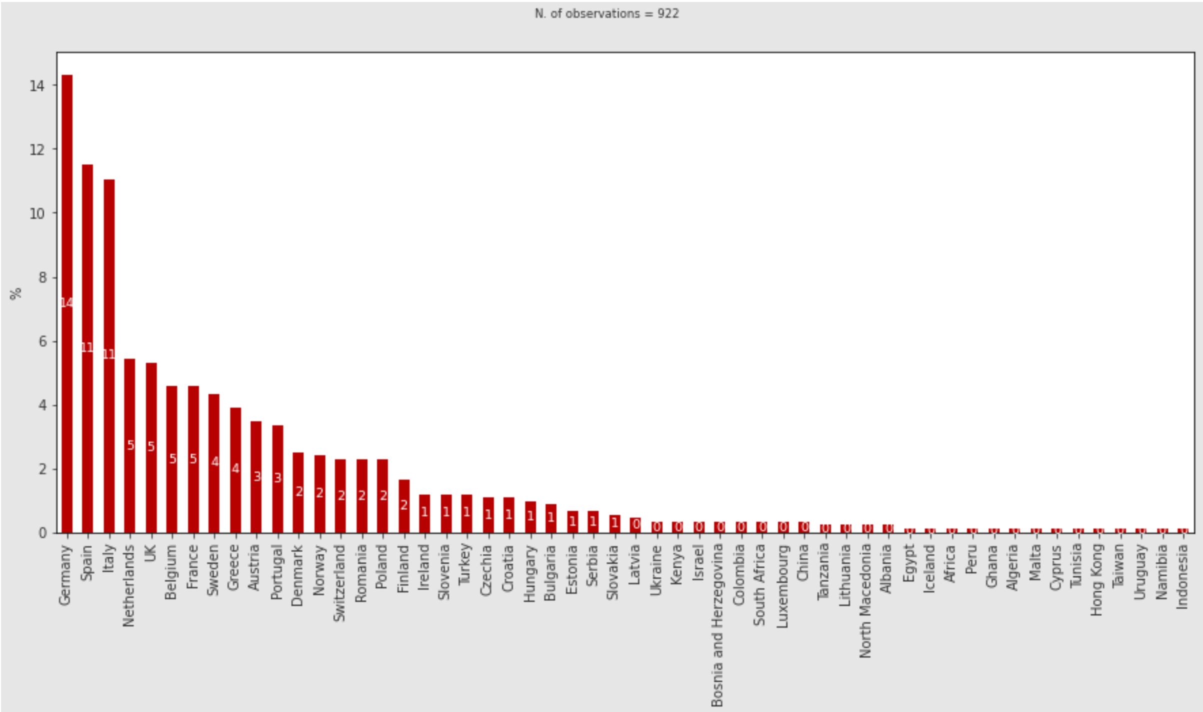


Figure 49. Distribution of responses per country.

Figure 50 shows the distribution of responses per stakeholder type. The two most strongly represented stakeholder types are Research institutes / centres of excellence/ competence centres and Higher education institutions (both 22%), followed by SMEs / start-ups (19%) and large companies (15%). Other stakeholders are public agency / ministry department (8%), Other (6%), Industry association (4%), NGOs (3%), and lastly Research funds (1%). Benchmarking the survey data with the data on the overall H2020 structure, showed no outliers.

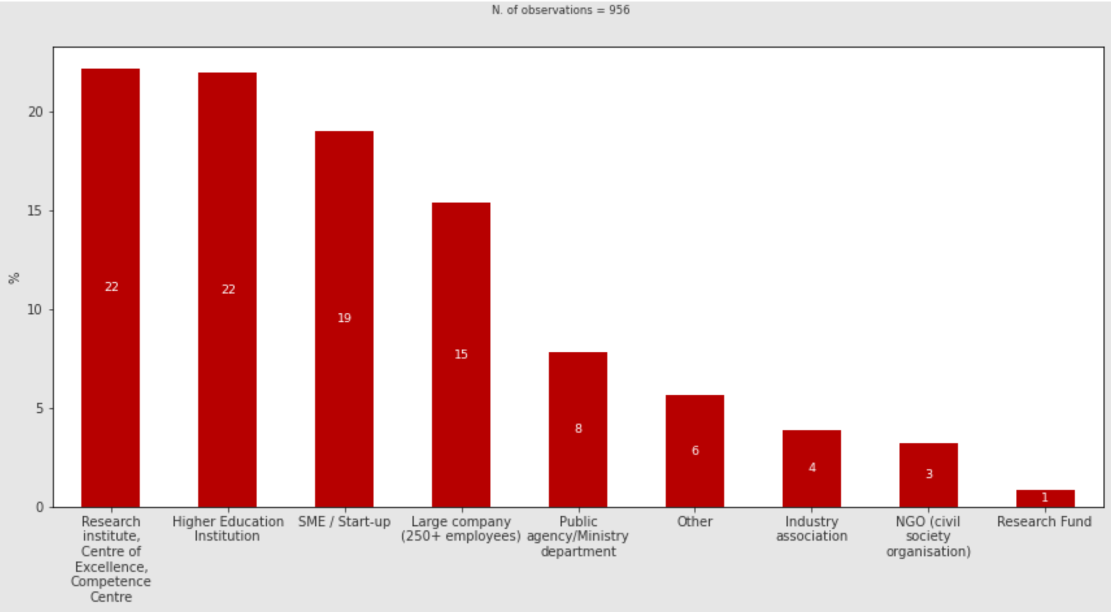


Figure 50. Distribution of responses per stakeholder type.

Figure 51 shows the distributions of the positions of respondents in the project. In total, 46% of the respondents functioned as a project partner without leading a WP. 37% of the respondents functioned as a WP Leader, and 17% of the respondents had a Project coordinator position.

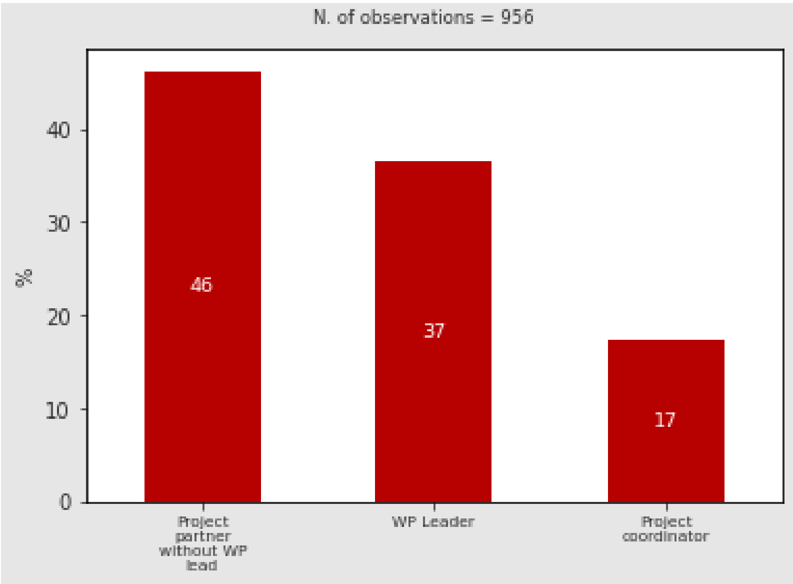


Figure 51. Distribution of responses per position.

Figure 52 shows the distribution of responses per type of project. RIA projects are by far most well represented with 43%, followed by CSA and IA projects (25% and 18% respectively). The remaining five project types are not significantly represented, with SMEs at the low end representing less than 1% of respondents. Compared to the H2020 projects in general, there is a slightly lower percentage of CSA projects (19%), and a higher percentage of IA projects (38%). The percentage of RIA projects is similar.

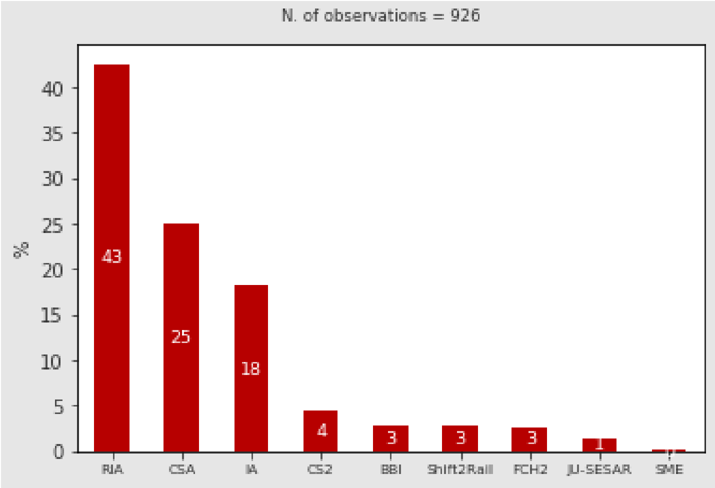


Figure 52. Distribution of responses per type of project.

2. Evidence and findings per societal challenge

2.1. Societal Challenge 2 “Food, Agriculture, Water and Bioeconomy”

2.1.1. Relevance and Coherence of the Intervention

Motivation for applying

One type of motivation for future applicants is related to technology and innovation considerations. The two main motivational drivers are ‘Addressing specific scientific or technical questions, problems and issues’ (82% to a very large and very large extent) and ‘Development of new processes, products and services’ (70%). The factors that matter the least were ‘Accessing funding for seed research’ (38%) and ‘Development of non-technological innovations’ (40%). Nevertheless, they remain tangible motivational drivers.

Figure 51. Q7: To what extent did the following factors encourage you to apply for H2020 funding under SC2 Agriculture, Food, Water and the Bioeconomy? Technology and innovation.

Climate and environment are another set of motivational drivers for applicants. The two main motivational factors are 'Increasing resource efficiency in processes' (71% to a very large and very large extent) and 'Addressing grand societal challenges related to the climate' (70%). The factors that matter the least were 'Reduction of the environmental impacts of the organisation' (29%) and 'Contribution to development that avoids GHG emissions' (47%). Nevertheless, they remain tangible motivational drivers.

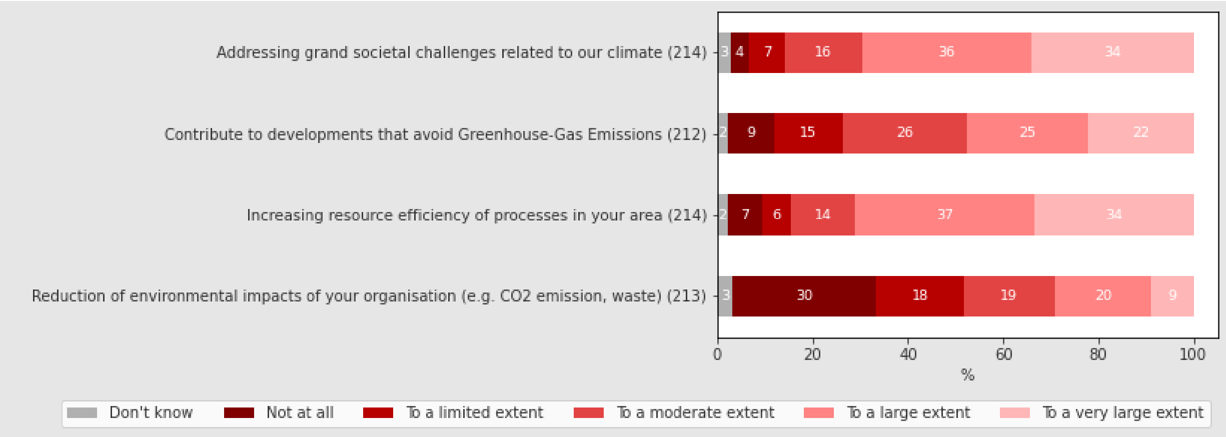


Figure 52. Q8: To what extent did the following factors encourage you to apply for H2020 funding under SC2 Agriculture, Food, Water and the Bioeconomy? Climate and environment-related.

Business development and competitiveness have been identified as one of the key motivations for applicants. The biggest share of applicants was driven by a motivation to increase the visibility of the organisation (66% to a large and very large extent). This driver is followed by the 'Increase of productivity and competitiveness of the organisation (49%) and 'Diversification of the organisation activities' (41%).

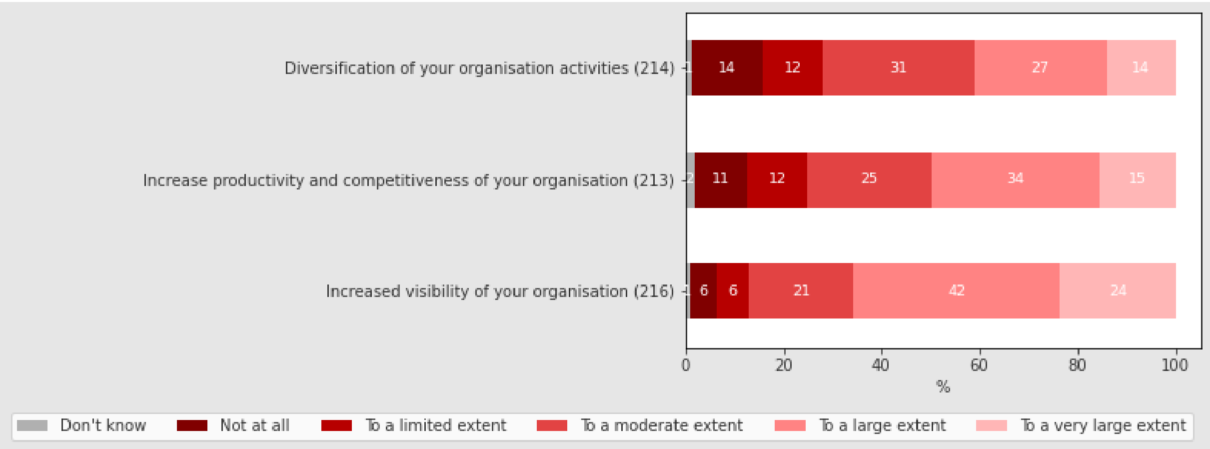


Figure 53. Q9: To what extent did the following factors encourage you to apply for H2020 funding under SC2 Agriculture, Food, Water and the Bioeconomy? Business development and competitiveness.

Collaboration is a major driver for participation in H2020 projects. Organisations were mainly willing to collaborate with other types of organisations (89% agree to a large and very large extent). Supposedly, this is an implicit acknowledgement of the value of the ecosystem as a whole. 'Development of non-EU collaborations' is less of a driver with 46% of the respondents for which it matters to a large and very large extent. 'Sharing a risk of a project' is the weakest of the three collaboration-related drivers (34% to a large and very large extent).

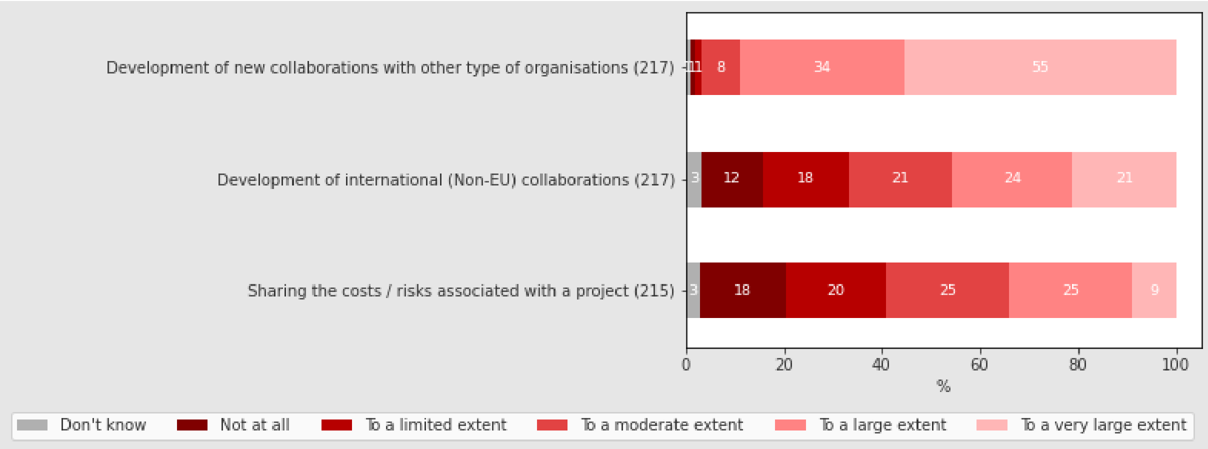


Figure 54. Q10: To what extent did the following factors encourage you to apply for H2020 funding under SC2 Agriculture, Food, Water and the Bioeconomy? Collaboration.

Needs and challenges

Between 25% and 78% of the respondents consider that their different needs and challenges have been addressed by the project to a large and very large extent. The challenge and needs which have been addressed to the highest extent are 'enable sustainable exploitation of natural resources' (78%), followed by 'supply sufficient food, feed, biomass and other raw materials' (50%) and 'foster innovation in rural and coastal areas' (50%). The challenges and needs which have been addressed to the lowest extent are 'maximise social and economic benefits from Europe's oceans" (24%) and 'provision of safe, healthy and affordable food' (38%).

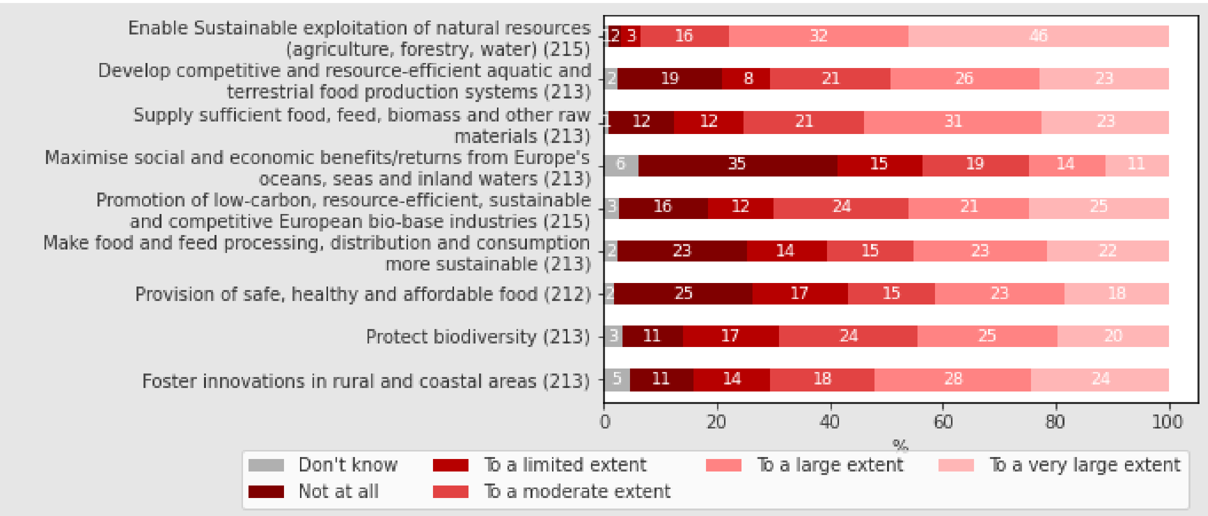


Figure 55. Q11: To what extent does your project address the following needs and challenges?

Collaboration

As pointed out previously, collaboration is a main motivational driver for H2020 participants. While the previous question was referring mainly to collaboration within the consortium, the one below targets collaboration with organisations outside the consortium. The intensity of collaboration was by far the highest with regards to research organisations (59% collaborated or co-led) followed by High Education Institutions (HEI) (56%). The lowest level of collaboration intensity was identified with regard to Research Funding Organisations (14%) and NGOs (19%).

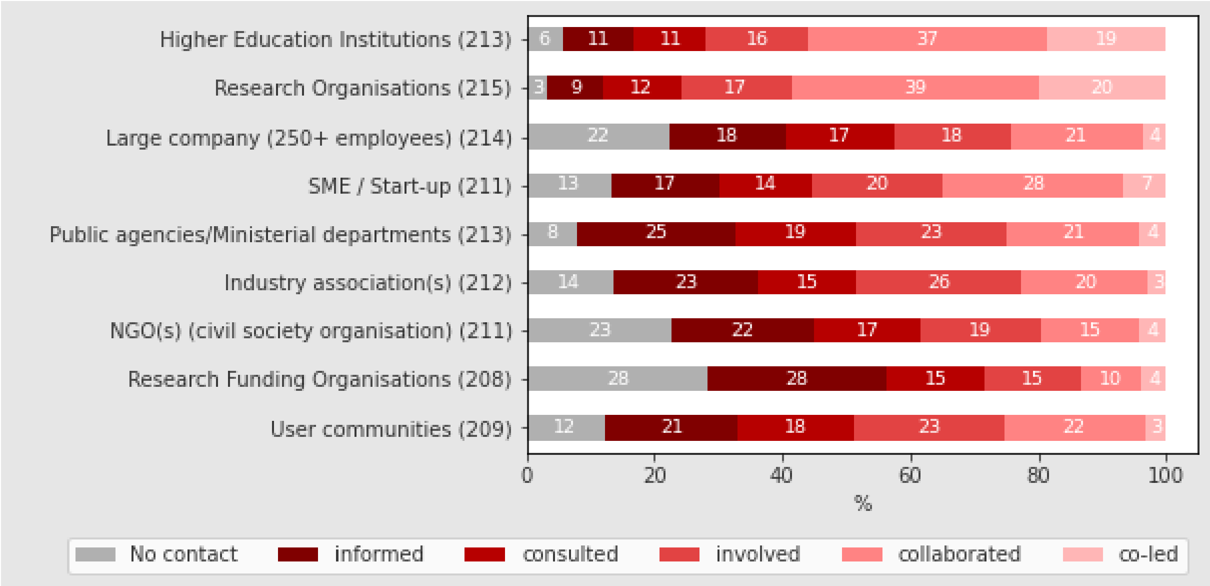


Figure 56. Q12: How intense was your collaboration with the following stakeholder groups outside the project consortium in the context of your project?

Some 60% of the respondents believed that all relevant stakeholder groups were addressed through the project activities. By responding 'Partially' the remaining 40% of the respondents believed that improvements were possible. Some of the recommendations for improvements are summarised after the table.

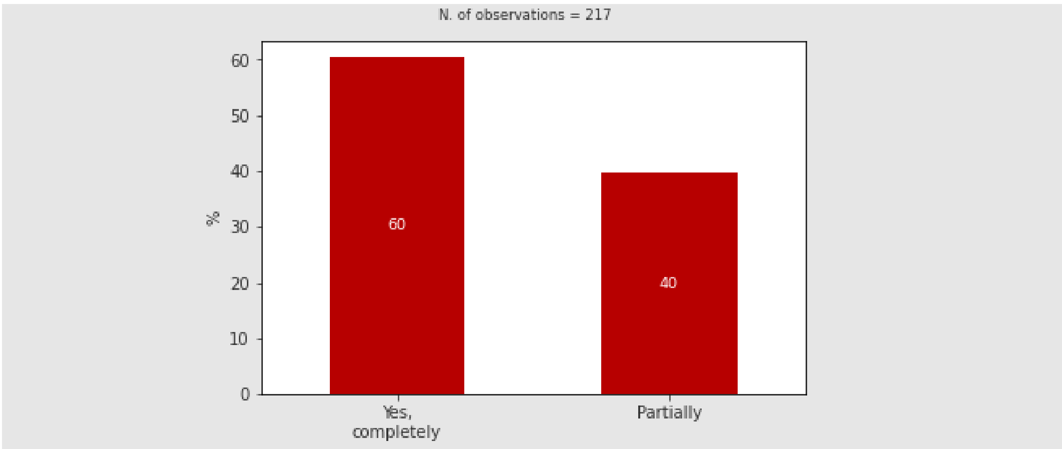


Figure 57. Q13: In your opinion, were all relevant stakeholder groups sufficiently addressed through the project activities?

Q14: Considerations with regards to stakeholder involvement:

- Well-designed projects include the most relevant potential partners. Including networks in the projects is also a factor for scalability.
- Covid-19 was a major factor in reducing the intensity of collaboration with external stakeholders.
- There are various tools which are instrumental for improving the intensity of collaboration such as newsletters, personal communication, invitations to meetings, presentations by the coordinator and other leaders, online advertising, blogs, workshops, conferences, interviews, publications (peer-reviewed, grey), lectures at universities etc.
- Some stakeholder groups are difficult to engage. For example, bigger players in the food system have shown no interest in being involved in the project. This includes larger conventional seed companies that are not yet or are only partly involved in organic seed production. Involving traders and retailers was also difficult. Elderly and digitally less competent are also harder to reach. It has to be noted that in certain cases, due to the novel nature of the projects, some of the commercial stakeholders and end users had reservations about the viability of the technology.

- A respondent pointed out that policymakers, crucial actors especially at the pan-EU level, are very hard to involve. Another respondent emphasised that it is difficult to engage small stakeholders and international organisations, particularly on transboundary basins due to historical conflicts.
- The involvement and engagement of public agencies and ministerial departments, who are leading the regulatory framework is difficult and should have been improved.
- Publishing a press release after the end of the project gives unprecedented visibility for the project across all the stakeholder categories.
- There is a difference between engaging stakeholders actively or simply informing them.
- The multi-actor approach has to be relaunched.
- Farmers were identified as key end users but they have not been fully engaged as effectively as they should have.
- Research-Policy collaboration within project logics might be rather challenging (policy and project logics often differ).
- Some stakeholders are not able to join/react often because they are addressed by so many projects.
- Language differences can create some barriers.
- From the point of view of a RIA, correct management of IPR is important, involving companies to grant the following developments.
- A project should have one WP on stakeholder engagement. This includes engaging a stakeholder advisory group from the very start as well as several stakeholder consultations.
- The academic research focus on leadership severely limits the abilities of non-academic partners and stakeholders to contribute.

In addition, it has to be pointed out that 53% of the respondents indicated that they have collaborated with non-European partners within the project.

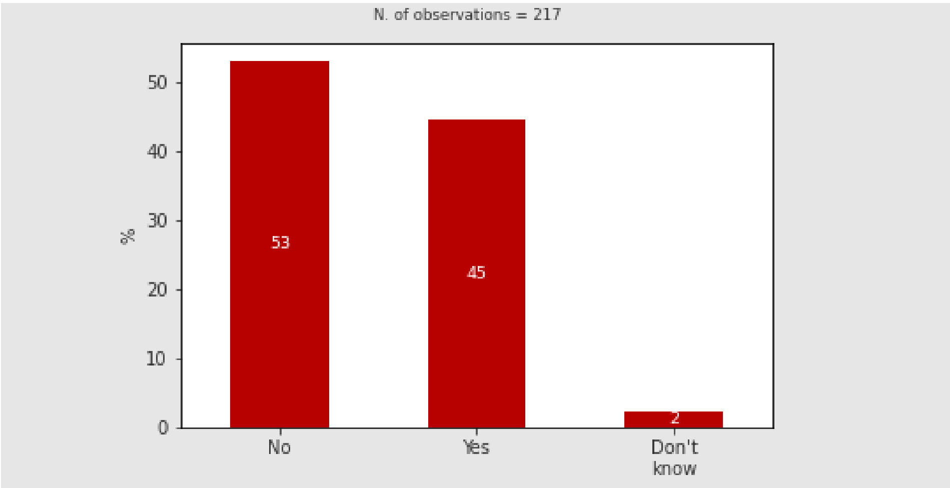


Figure 60. Q15: Have you collaborated with non-European partners as project partners in your project?

Those who collaborated with non-European partners pointed to several major benefits of this collaboration. ‘Development of know-how’ is the biggest identified benefit (77% - to a large or very large extent) followed by ‘Development of new, additional partnerships’ (67%). ‘Access to new markets’ and ‘Reduction of the environmental impact of the organisation’ have been the two smallest benefits (12% and 20% respectively).

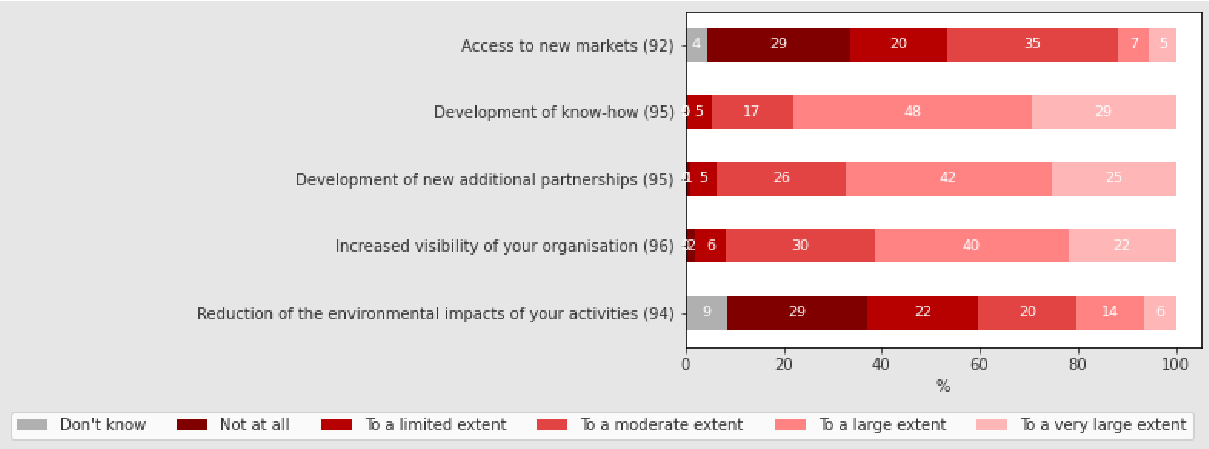


Figure 58 Q16: To what extent have you experienced the following benefits from the international cooperation in your project?

It has to be pointed out that some 34% of the respondents consider that cooperation with non-European partners contributes to a large or very large extent to improving the European position in the global competition. Some 33% think this advancement is to a moderate extent. Some 17% think it is either to a very limited extent or not at all while the remaining 15% either don't know or think it is too early to tell.

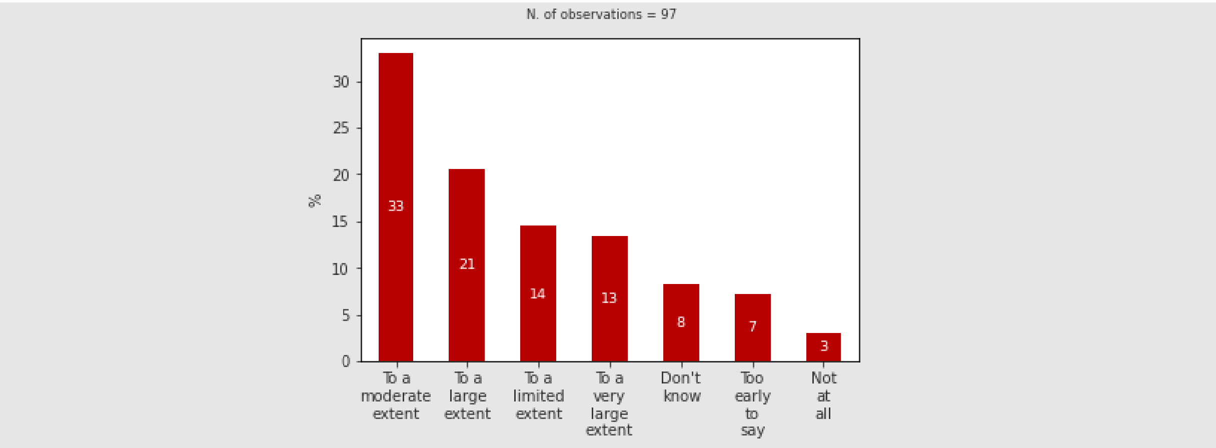


Figure 59 Q17: Has the cooperation with non-European partners in H2020 contributed to improving the European position in the global competition?

2.1.2. Effectiveness of the intervention

Results of the intervention

The answers to the survey revealed a high level of alignment between the objectives of the projects and their results. Some 87% of the respondents considered that these are fully aligned or aligned to a large extent. For 2% of the respondents, they are aligned to a limited extent.

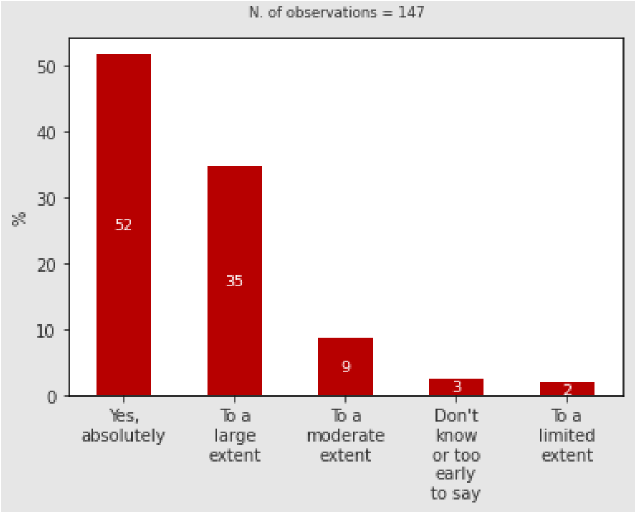


Figure 60. Q6: Are the results of your project in line with its objectives?

Between 28% and 75% of the respondents assess that the project contributed to a large or very large extent to the improvement of different aspects of expertise.

'Contribution to knowledge and capacity building' and 'Contribution to scientific and technological development' stand out as the aspects of expertise which have been improved to a large or very large extent (75% and 63%).

'Contribution to market and business development' has been improved to the lowest extent as only 28% of the respondents consider that it has been improved to a large or very large extent.

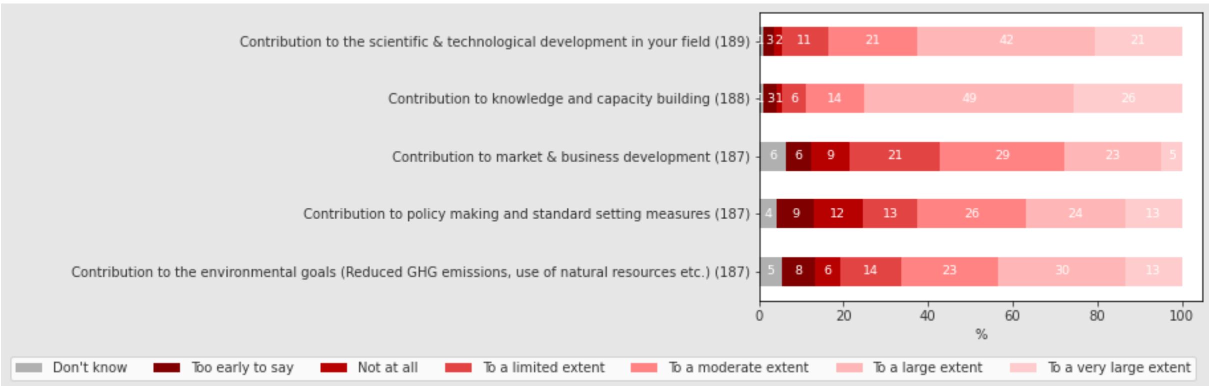


Figure 61 Q29: How successful was your project in terms of contributing to the following dimensions in your area of expertise?

Scientific results

Between 59% and 87% of the respondents assess that different scientific results have been fully achieved or achieved to a large extent. 'Better understanding of the subject' stands out as the scientific result which has been achieved to the highest extent (87%). It is followed by 'Better access to state-of-the-art research' (73%) and 'Publications in peer-reviewed journals' (63%).

There is no (anticipated) scientific result which stands out with a low extent of achievement, the lowest being 'Researchers trained' with 59%.

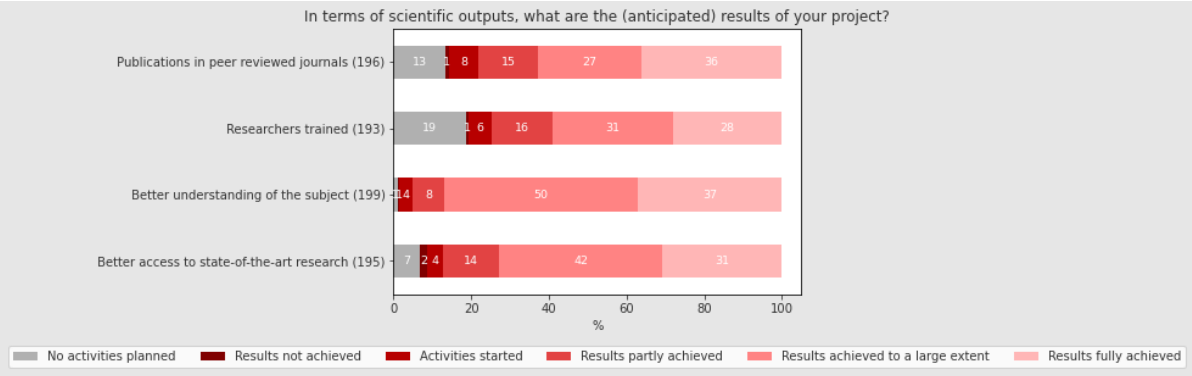


Figure 62 Q18: In terms of scientific outputs, what are the (anticipated) results of your project?

Technology and Innovation related results

Between 21% and 58% of the respondents assess that the technological development results have been fully achieved or achieved to a large extent.

'Expansion of basic knowledge for technological development' and 'New research tools, models, simulations' stand out as the technological development result which has been achieved to the highest extent (58% and 57%).

'Increasing the safety of technologies and components' and 'Cost reduction of technology'' are the anticipated technological development results which stand out with a low extent of achievement (full or to a large extent) (21% and 25% respectively).

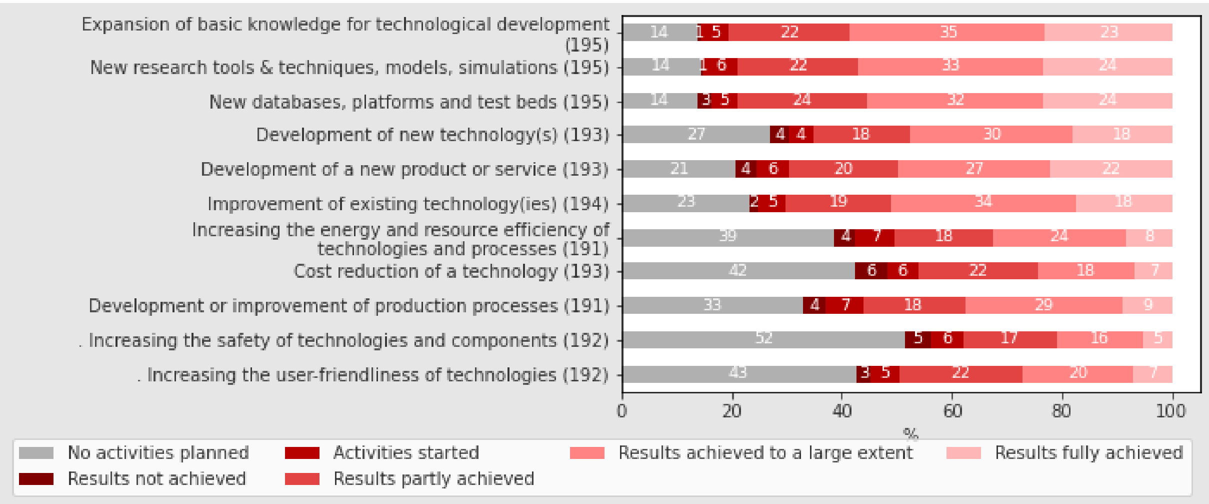


Figure 63 Q19: In terms of technological development outputs, what are the (anticipated) results of your project?

In terms of the contribution of the project to H2020's desired outcomes in Technology and Innovation, the respondents identified 'More sustainable agriculture and forestry management' and 'Solutions across technology fields and sectors' as the biggest achievements (56% and 52% respectively think that their projects contributed to these outcomes to a very large or large extent). On the other side of the spectrum, the outcomes achieved to the least extent are 'Test, demonstrate and scale-up of marine and maritime technologies, products and services' (13%) and 'New food, fibre and other bio-based products and processes with minimised inputs' (25%).

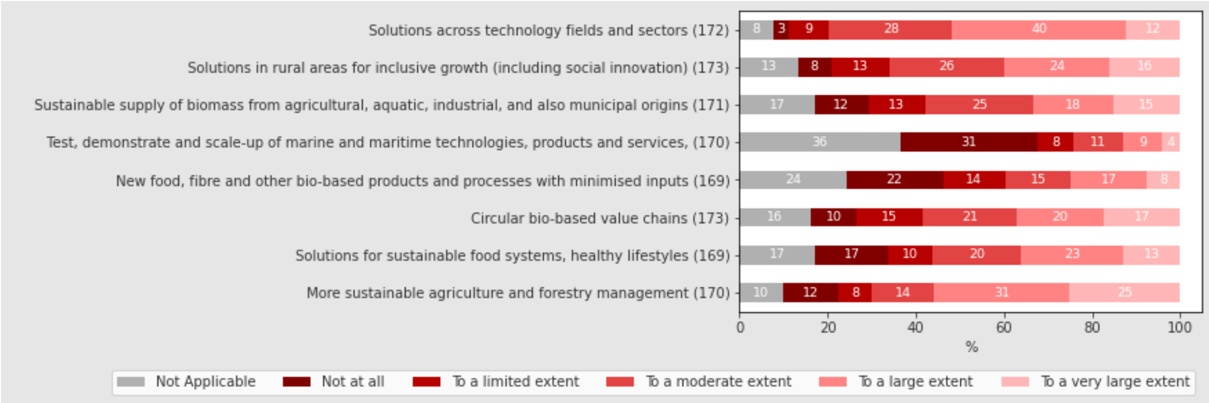


Figure 64 Q30: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Technology and Innovation.

Between 22% and 50% of the respondents assess that the system development results have been fully achieved or achieved to a large extent.

'Demonstration or pilot feasibility of technological solutions' and "Integration of technology' are the system development result which has been achieved to the highest extent (50% and 46%).

'Developing innovations in marketing and sales', 'Developing of organisational innovations' and 'Developing of social innovations' are the anticipated system development results which stand out with a low extent of achievement) (22%, 25% and 26% respectively think they have been achieved fully or to a large extent).

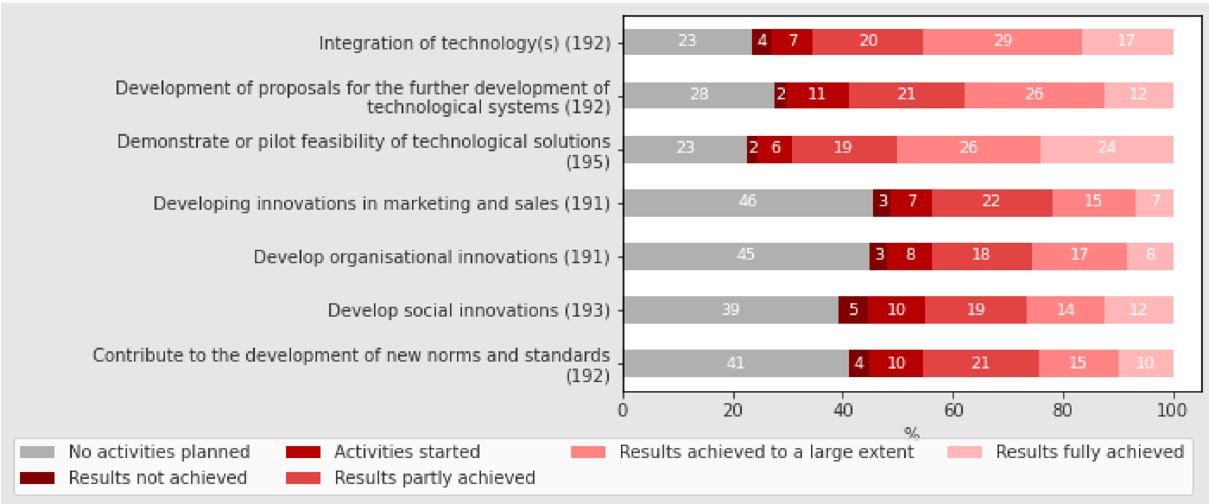


Figure 65 Q21: In terms of system development, what are the (anticipated) results of your project?

With regards to Technology readiness a significant share of the respondents (28%) considers that the TRL concept cannot be applied to their project. More than one-fifth of the respondents (21%) consider their overall TRL level was TRL 2 followed by TRL 4 (18%) and TRL 3 (14%). An insignificant number of projects have TRL levels 1, 7, 8, 6 and 9.

Data does not allow comparison between TRL levels at the start and the end of the same project. Nevertheless, given that the number of TRL2 and TRL3 projects went down significantly, it could be said with high probability that some of the projects moved up to TRL5 (up 25%), TRL6 (up three times) and TRL7 (up four times).

An additional analysis was done regarding the distribution of types of actions. This showed that for the highest percentage of CSA projects, the TRL was not applicable. IA projects, however, showed the highest percentage of projects in the TRL 3 or TRL 4 stage. For RIA projects there was no particular answer that stood out.

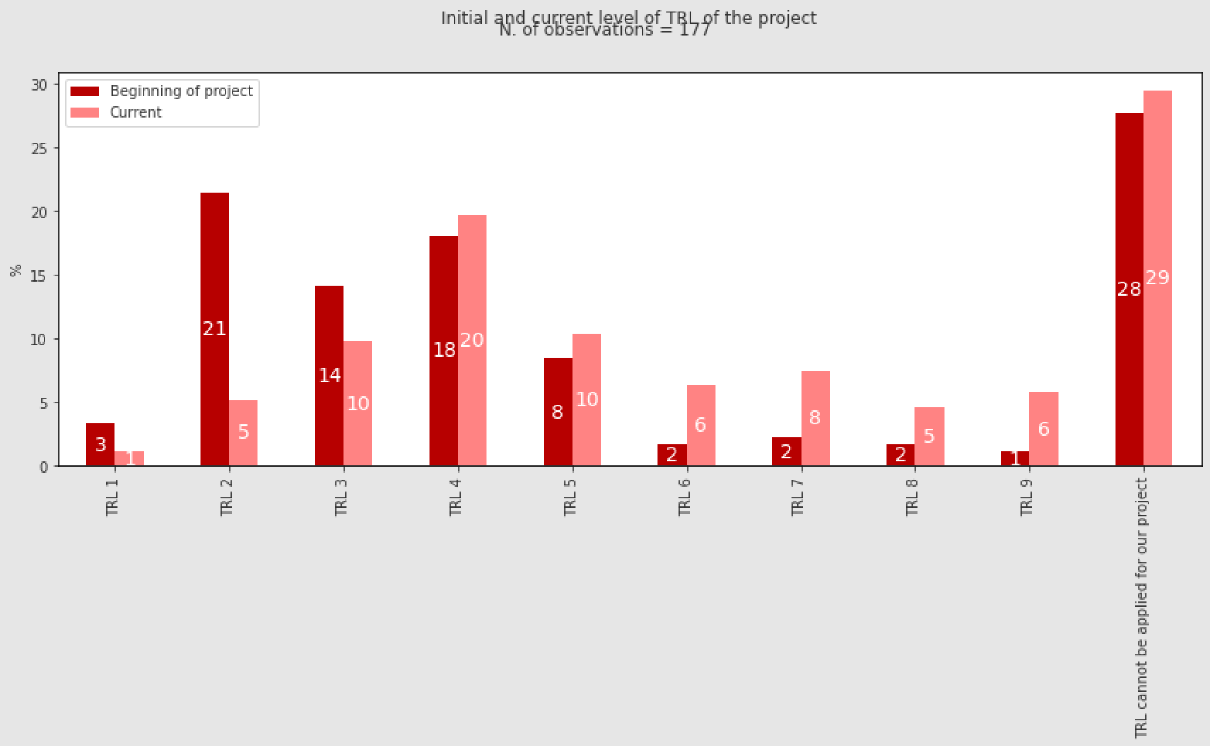


Figure 66 Q22: What was the overall level of Technology-Readiness at the beginning of the project (TRL)? And Q23: What is the current overall level of Technological-Readiness of your project's technological development?

The targeted technological readiness for more than one-third of the projects was TRL2 and TRL3 at the start of the project. One quarter were TRL4 and TRL5 while only 7% were TRL6 and higher.

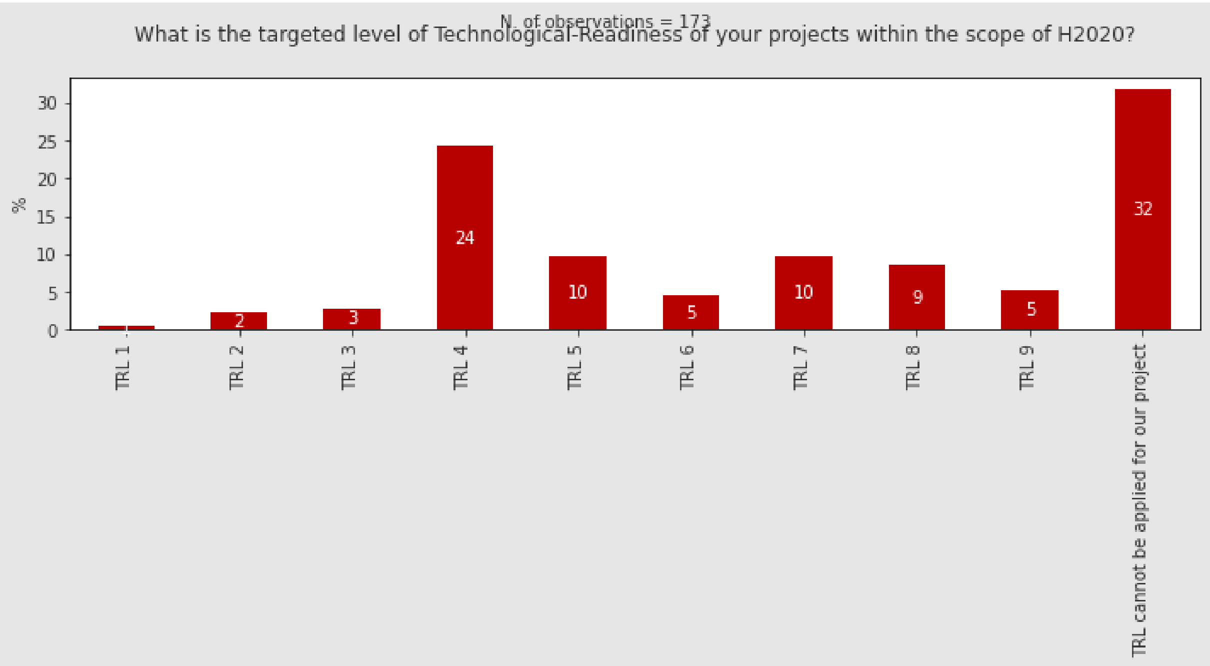


Figure 70. Q24: What is the targeted level of Technological-Readiness of your projects within the scope of H2020?

Knowledge and Capacity related results

Between 21% and 64% of the respondents assess that the project influenced their organisation to a large or very large extent.

'Intensified of R&D in collaboration with new organisations' and 'Increased focus on interdisciplinary research' are the two aspects for which the project has influenced the organisations to a large and very large extent (64% and 61%).

The two aspects which the project influenced the most (to a large and very large extent) are 'Intensified collaboration on R&D with new organisations' (64%) and 'Increased focus on interdisciplinary research' (81%).

'Increased focus on risk-oriented research', is the aspect of the organisation which stand out as influenced the least. Only 21% of the respondents thought it had been influenced to a large or very large extent.

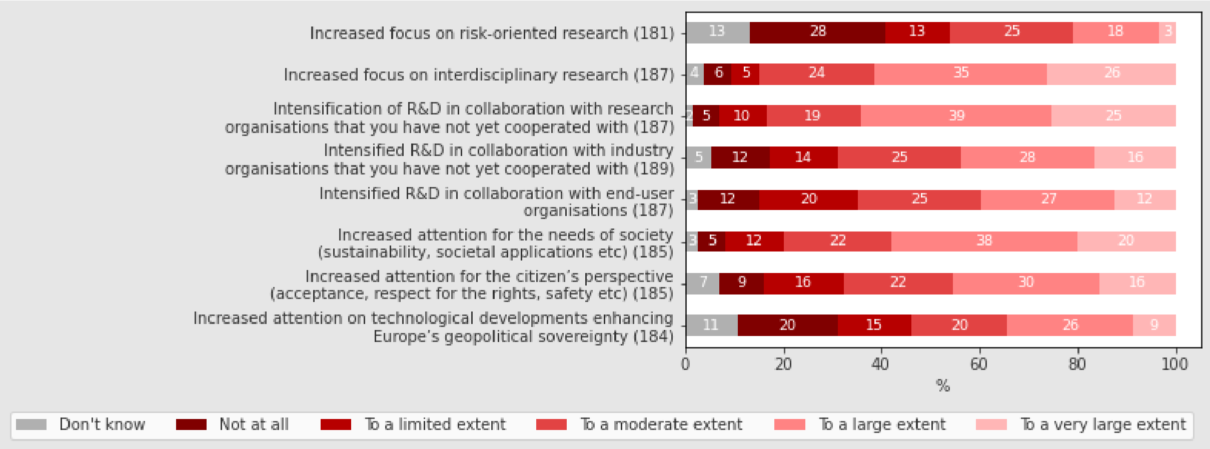


Figure 71. Q26: To what extent did your project influence the following aspects of your organisation?

With regard to the contribution of the project in terms of enabling several desired outcomes, 'Strengthening R&I capacities in your area' and 'EU excellence in science and innovation' stand out as the two outcomes achieved to the largest extent (65% and 59% respectively). The two desired outcomes which have been achieved to the lowest extent are 'Improve current European observing, surveying and monitoring capabilities' (36%) and 'Improved knowledge, infrastructure and capacities for upscaling' (39%).

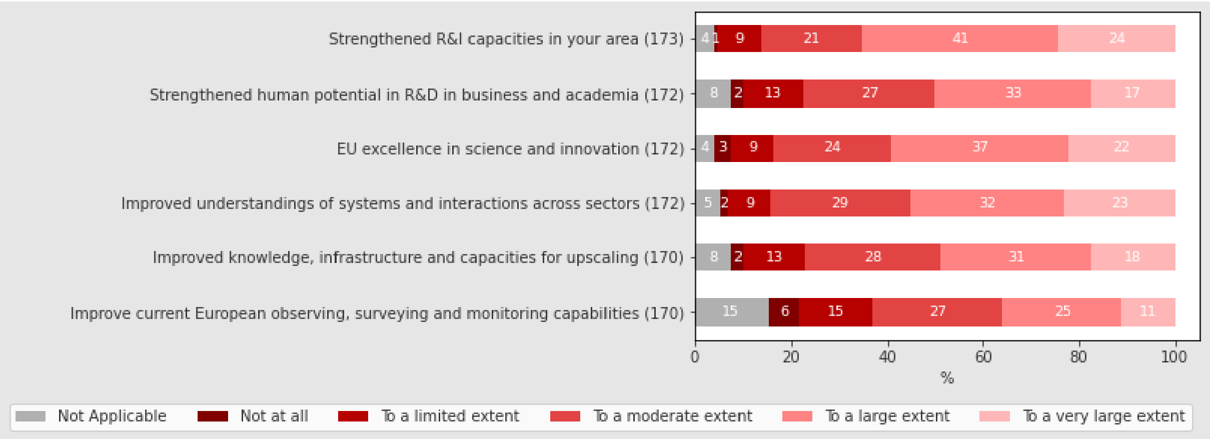


Figure 67 Q31: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Knowledge & Capacity.

Coordination and collaboration

Between 32% and 70% of the respondents considered that their projects contributed to the different desired outcomes of Horizon 2020.

The first four outcomes have been achieved almost to an identical extent at around 65-70% of the respondents considering the contribution to be to a large or very large extent. 'Stronger involvement of civil society in R&I' stands out as the outcome to which projects have contributed the least.

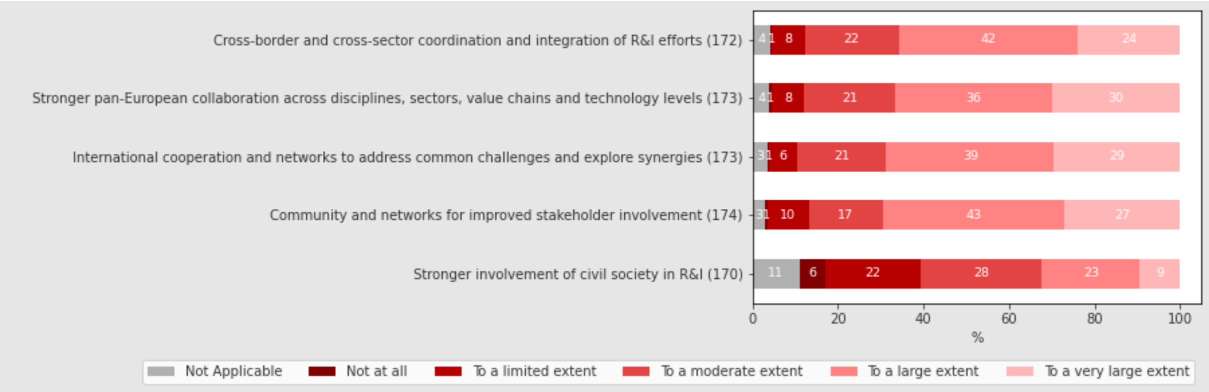


Figure 68 Q32: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Coordination & Collaboration.

Markets and business

Between 9% and 36% of the respondents assess that the market development results have been fully achieved or achieved to a large extent.

'Development of marketable products or services' and 'Creation of new jobs' are the market development result which has been achieved to the highest extent (36%).

'Creation of a start-up' and 'Creation of a spin-off, are the anticipated market development results which stand out with a low extent of achievement (full or to a large extent) (10% and 9% respectively).

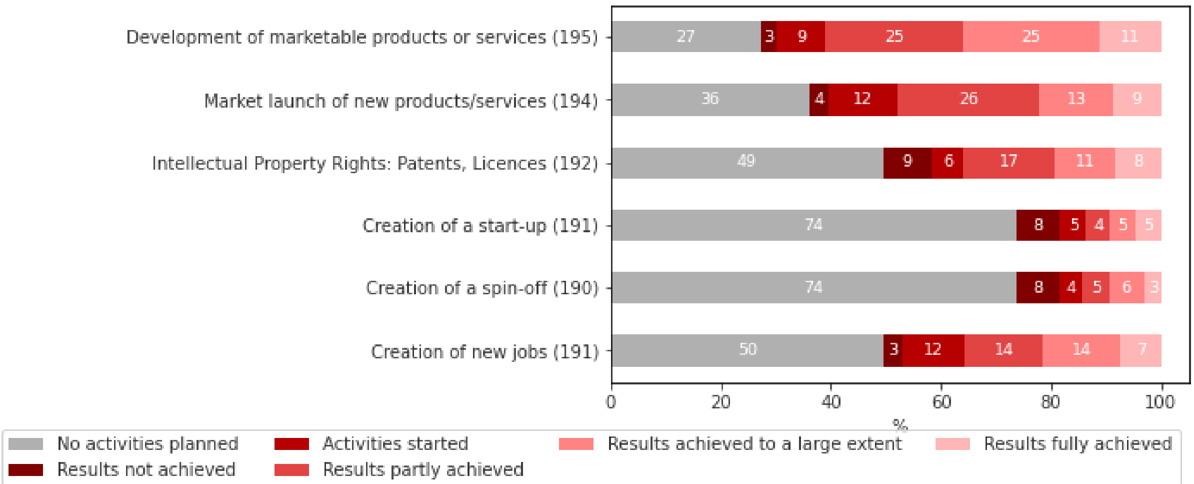


Figure 69 Q20: In terms of market development, what are the (anticipated) results of your project?

Some 39% of the respondents think that the project has contributed to a large or very large extent to the improvement of time-to-market of technological solutions. Inversely, 16% consider that this has happened to a limited extent (10%) or not at all (6%). Some 18% of the respondents are not aware of the effect of the project on the 'time-to-market' of new solutions.

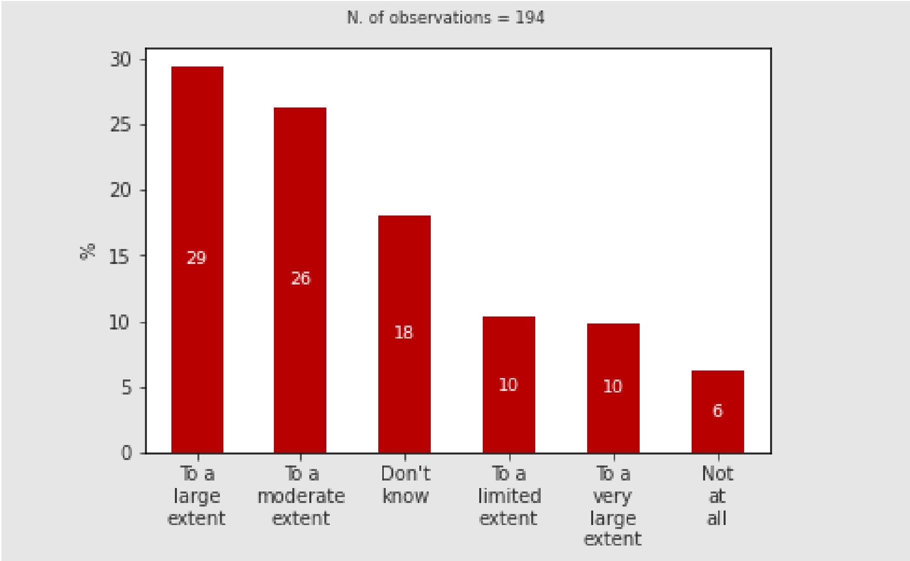


Figure 70 Q25: Has the project contributed to improve the "time-to-market" of new solutions?

No more than 8% of the respondents consider that the project led to a 20% or more increase in turnover, employment or profit. Between 25% and 30% of the respondents think that there has been an incremental increase between 1% and 10% for these three aspects. Between 46% and 64% of the respondents either don't know if there has been an increase in these three aspects or think that there has been no change. There is only a small difference between the answers with regard to the different economic benefits. Profit is the one which is considered to be the least impacted with 65% who either do not know or think there has been no change. From those who think there have been economic benefits, the majority consider an incremental increase between 1-10% for all impacts.

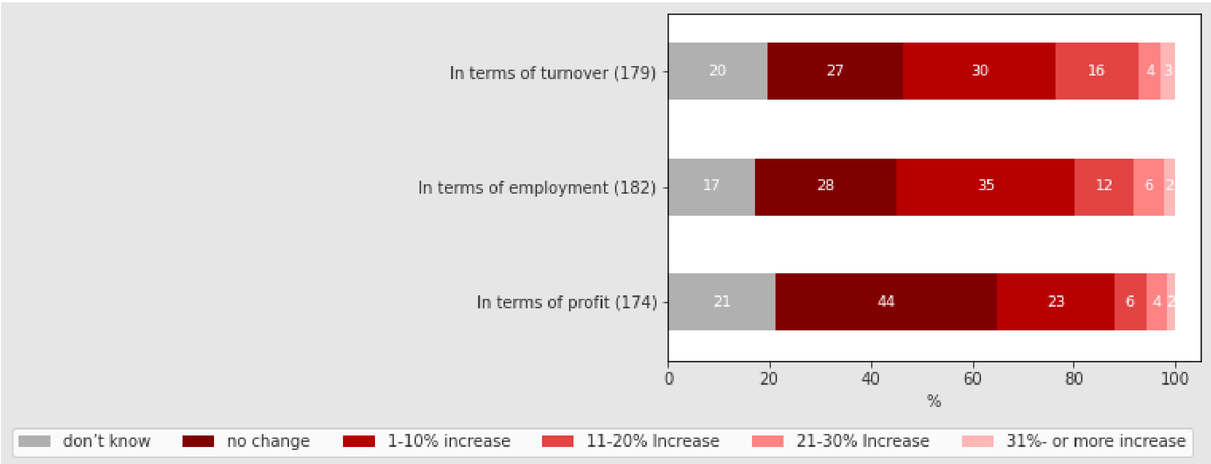


Figure 71 Q27: To what extent has your participation in H2020 led to the following economic benefits (or is it expected to do so after project completion) in your operational unit? Please provide best estimates.

Between 27% and 43% of the respondents assess that the project influenced their competitiveness to a large or very large extent: nationally (38%), in Europe (43%) or internationally (27%). Around 28-30% think that the increase has been to a moderate extent. Between 28% and 44% of the respondents either don't know or think that the project influenced their competitiveness nationally, in Europe or internationally not at all or to a very limited extent.

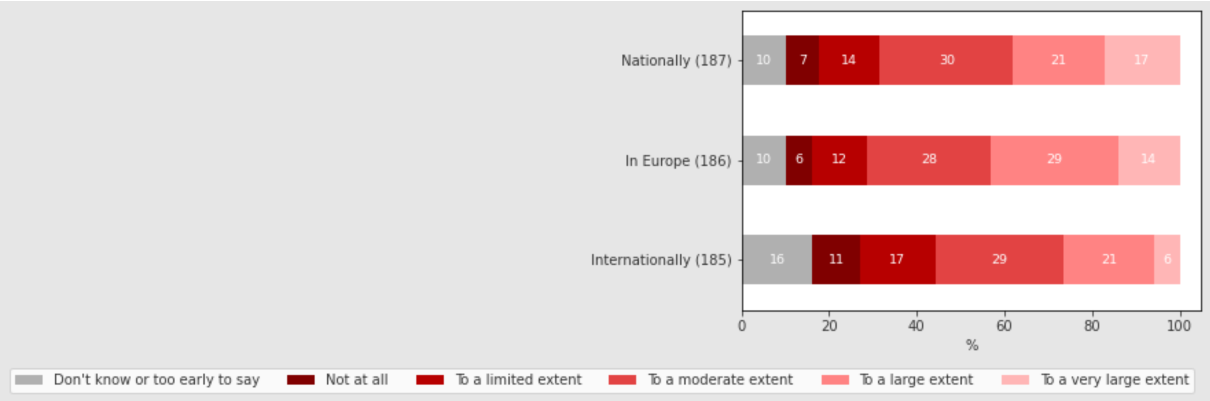


Figure 72 Q28: Do you consider that your project contributed to the increase of the overall competitiveness of your operational unit?

Between 13% and 34% of the respondents think their project contributed to a large or very large extent to the different desired outcomes. The share is the highest for the outcome 'Development of inclusive value chains' (34%) followed by 'Provision of competitive bio-based products'. The share is the lowest for the outcome 'Removal of barriers to market entry'. It has to be noted that a significant portion of the respondents think the contribution has been moderate. If they are taken into consideration 'Higher consumer awareness and acceptance' comes second.

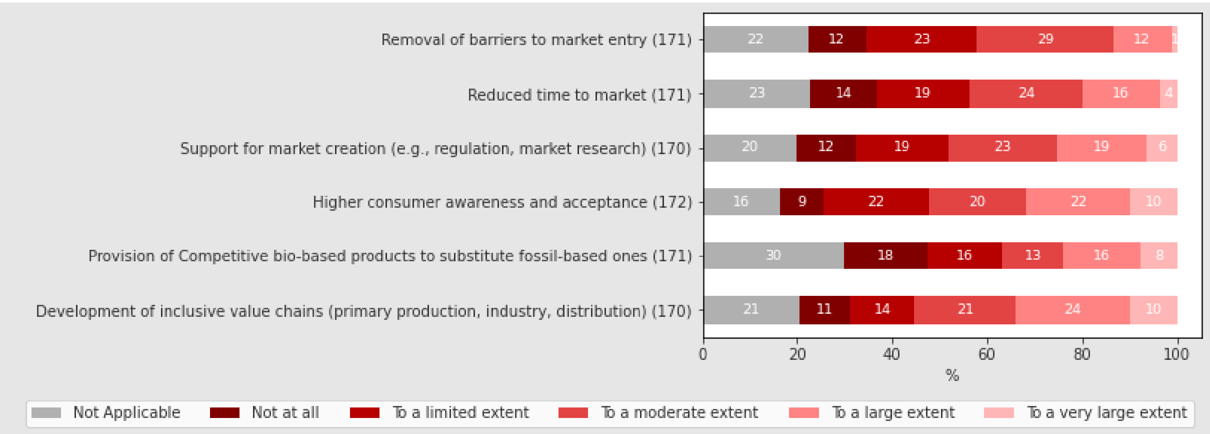


Figure 73 Q33: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Market & Business.

Policies and standards

Between 21% and 37% think the projects contributed to the desired outcomes in terms of policies and standards. 'Improved understanding of socio-economic trends and prospects related to food and health consumption and bio-based products' comes first with 37% of the respondents while 'Citizens' engagement and promote of participative governance' and 'New and/or improved standards for products and processes' come last with 21% and 26% respectively.

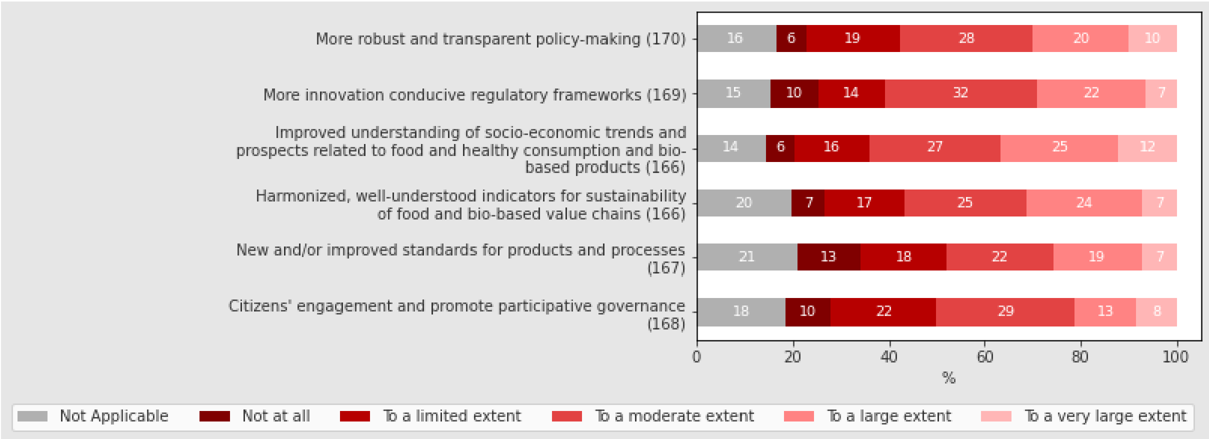


Figure 74 Q34: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Policies & Standards.

Barriers and enabling factors

Between 7% and 27% of the respondents consider that different types of barriers impede the successful uptake of their projects. The two barriers which stand out are ‘Limited financial resources for the implementation of project results’ (27%) and ‘Impeding legal framework’ (23%). If respondents who chose that the influence is moderate are added to the figures then ‘Lack of internal organisation support for implementation’ and ‘High economic risk’ are also tangible with 39% and 38% respectively. Overall, all of the mentioned barriers are valid.

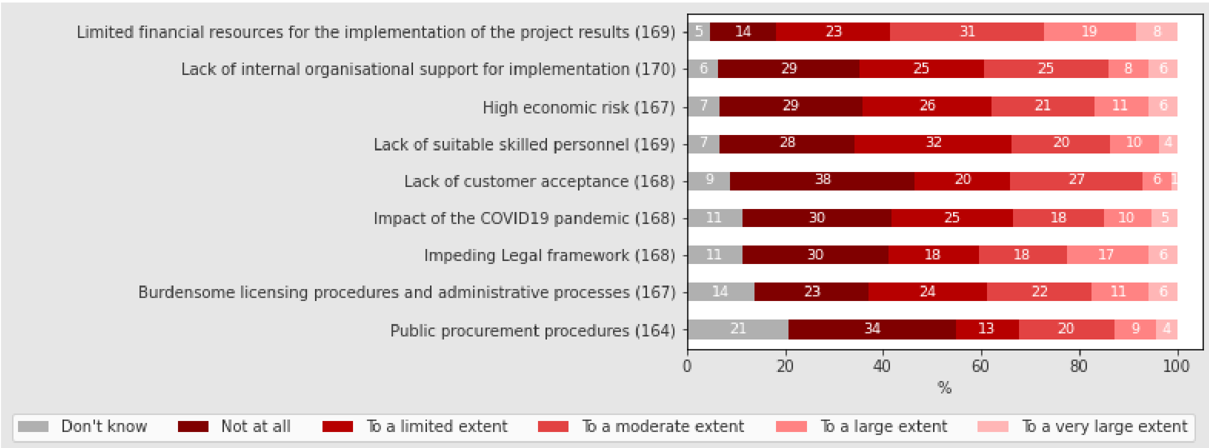


Figure 80. Q35: Barriers and enabling factors: Do you see barriers that impede a successful uptake of results of your project?

Dissemination, exploitation and communication

The huge majority of respondents think that dissemination, exploitation and communication activities have been both useful (76% to a large and very large extent) and sufficient (66%). Less than 10% don’t know or consider that they have been neither useful nor sufficient.

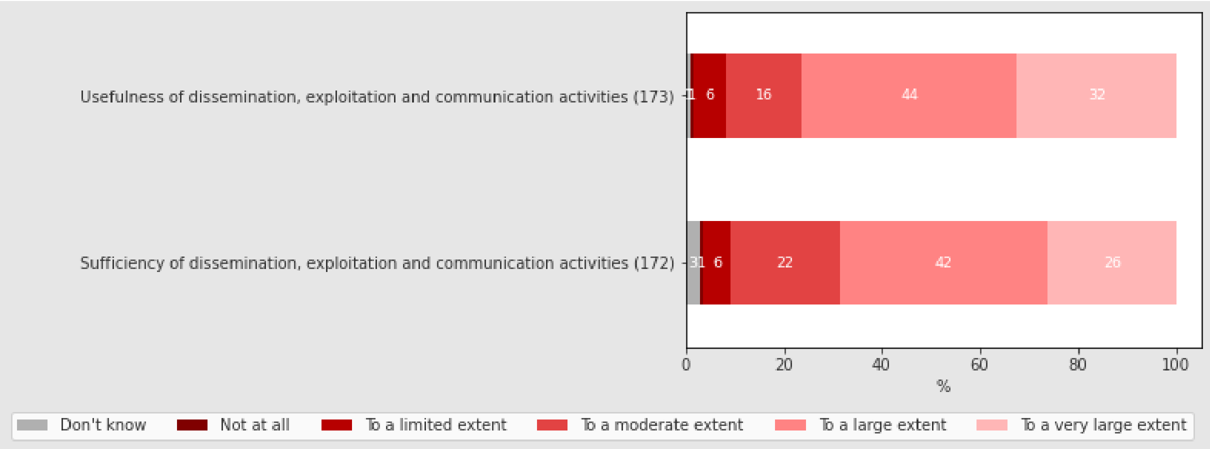


Figure 81. Q36: To which extent have the dissemination, exploitation and communication activities been useful and sufficient in the uptake of your project results?

2.1.3. EU added value

Between 45% and 83% of the respondents think that H2020 provided an EU-added value in several aspects to a large and very large extent. The aspects of 'Multi-cultural consortia' and 'Diversity of partner profiles' come first with 83% and 82% respectively. They are followed by 'Funding opportunities for specific topics' (79%). The lowest value added is on technical support provided (45%), 'Flexibility given to respond to technological developments' (45%) and 'Flexibility given to respond to socio-economic needs' (50%).

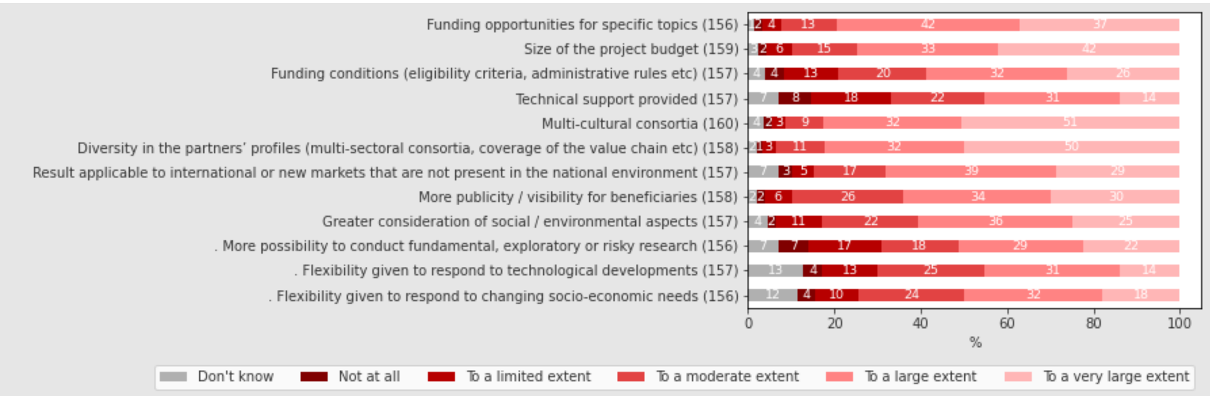


Figure 75 Q50: To what extent do you see added value from funding Horizon 2020 projects compared to funding on a national or regional level?

Some 75% of the respondents answered that the project would not have been implemented; 73% - the scope would have been reduced; 34% that it would have been implemented with other partners; 21% that it would have been funded on a national or regional level; 26% that its timeline would have been extended; and 42% that it would have been delayed.

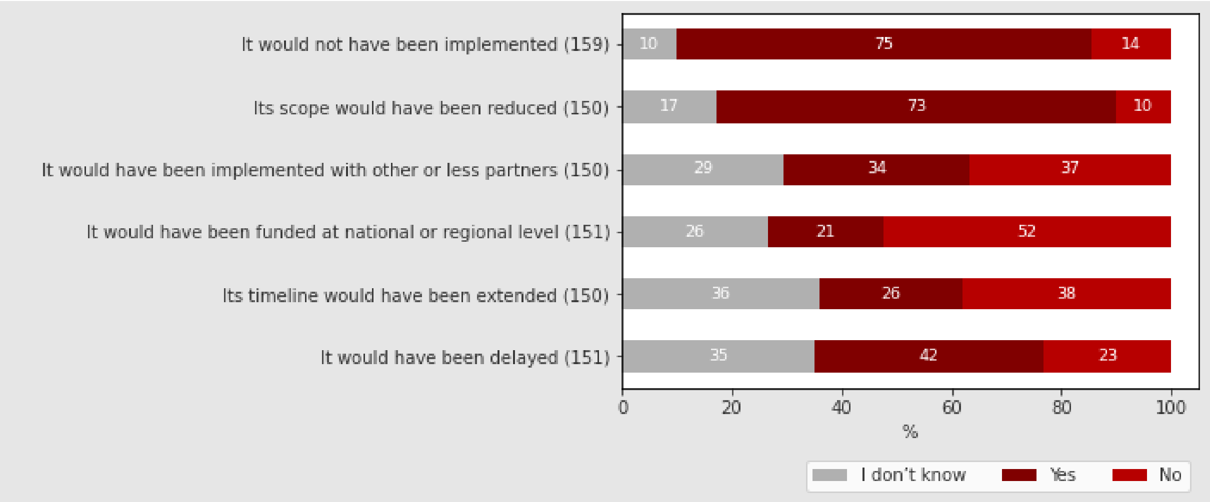


Figure 76 Q51: Without support from H2020, what would have happened to your project?

2.1.4. Summary

Relevance and coherence

In terms of technology and innovation, the two main **motivational drivers** for respondents are 'addressing specific scientific or technical questions, problems and issues' and 'development of new processes, products and services'. 'Accessing funding for seed research' did not appear to be of the same importance. As far as climate and environment are concerned, 'increasing resource efficiency in processes' and the need 'to address grand societal challenges related to climate' were the biggest motivators for participation in the Framework Programmes. From a business and competitiveness point of view, 'improving the visibility of the organisation' exceeded significantly other motivational factors such as 'increasing the productivity and competitiveness of the organisation' and 'diversification of the organisational activities'. Collaboration is a strong driver for participation in FPs, especially the 'development of new collaborations with other types of organisations' and much less so 'developing collaborations with non-EU organisations' and 'sharing the risks of a project'.

The needs and challenges of projects have been addressed to varying extents. *'Enabling sustainable exploitation of natural resources'* has been addressed to the highest extent. The challenges and needs which have been addressed to the lowest extent are the *'maximisation of social and economic benefits from Europe's oceans'* and *'provision of safe, healthy and affordable food*'.

Collaboration is key for H2020 projects, and its intensity was the highest with *Higher Education Institutions* and *Research Organisations* which exceeded by far collaboration with other types of stakeholders. On the other end of the spectrum, collaboration was lowest with *NGOs* and *Research Funding Organisations*.

With regards to **involving stakeholders** in the work of the projects, 40% considered this to be done only partially. Covid-19 was a major reason for that. Moreover, certain groups were very difficult to engage such as big players in the food system or farmers. The difference between informing a stakeholder of the project's progress and simply informing them should be kept in mind. **Collaboration with non-EU partners** took place for less than half of the respondents but those who collaborated saw benefits from it the main one being *the 'development of know-how'*. *'Access to new markets'* has not been identified as a major benefit. Respondents are split with regards to the contribution of cooperation with non-EU partners on European position in global competitiveness: one-third considered this to be the case to a large and very large extent; one-third thought the impact was moderate and roughly one-third either did not know or were sceptical about the impact.

Effectiveness

According to survey responses, there is a high level of alignment between project objectives and results. From a **knowledge** perspective, the project contributed to the largest extent to *'knowledge and capacity building'* and *'scientific and technological development'*. 'Contribution to market and business development' has been the lowest. In terms of **scientific results**, respondents consider that the project contributed to the largest extent to a *'better understanding of the subject'* and *'better access to state-of-the-art research'.*

With regards to **technology and innovation**, the share of respondents who consider results have been fully achieved or achieved to a large extent is lower than for knowledge- and science-related results. 'Expansion of basic knowledge for technological development' and 'New research tools, models, simulations' are the two technological development results which have been achieved to the highest extent. 'Cost reduction of technology' and 'increasing technology safety' have been achieved to the lowest extent. In terms of technological development outputs, the respondents identified 'More sustainable agriculture and forestry management' and 'Solutions across technology fields and sectors' as the biggest achievements. **System development results** are considered as achieved fully or to a large extent by no more than half of the respondents. 'Demonstration or pilot feasibility of technological solutions' and 'Integration of technology' are the system development results which have been achieved to the highest extent. However, different types of innovations in marketing and sales and organizational and social innovations are on the low end.

The **TRL concept** has not been considered relevant by almost one-third of the respondents. The technology readiness for more than one-third of the projects was TRL2 and TRL3 at the start of the project. One-quarter were TRL4 and TRL5 while only 7% were TRL6 and higher. Data does not allow comparison between TRL levels at the start and the end of the same project. However, the fact that the number of TRL2 and TRL3 projects went down while TRL6, TRL7 and TRL 8 went up certainly means that overall, the projects increased their maturity level.

Organisational knowledge has been influenced to a large and very large extent for 21%-64% of the respondents, the largest focus being on 'intensified collaboration on R&D with new organisations' and 'increased focus on interdisciplinary research'. At the same time 'Increased focus on risk-oriented research' has been influenced by only one-fifth of the respondents. Around two-thirds of the respondents overwhelmingly validated the assumption that projects strengthened R&I capacities and EU excellence in science and innovation.

With regards to **coordination and collaboration**, four of the outcomes have been achieved to a large or very large extent by two-thirds of the respondents. These include cross-border and cross-sectoral integration; stronger pan-European collaboration across sectors; networks to address common challenges; and community and networks for improved stakeholder involvement.

Market and business have not been identified as a large or very large achievement by more than one-third of the respondents. 'Development of marketable products or services' and 'Creation of new jobs' are on the highest end while 'Creation of start-ups and spin-offs' have been achieved to a large or very large extent by only 10% of the respondents. Almost 40% think the time-to-market of technological solutions has been improved. The impact of the project on the microeconomic bottom line – turnover, employment, profit - of the project is very limited. A slightly bigger share of the respondents thinks the project improved their competitiveness, mostly in Europe and nationally and to a lesser extent – internationally. The relatively low level of perceived impact on market and business is also reflected in the perceived impact on different types of related outcomes. The outcomes 'Development of inclusive value chains' and 'Provision of competitive bio-based products' have been achieved to a large and very large extent by one-third of the respondents. At the same time, the outcome 'Removal of market barriers''

In terms of policies and standards, desired outcomes have been achieved to a large and very large extent by 21-37% of the respondents. Key policy outcomes such as 'More robust and transparent policy making' and 'More innovation conducive regulatory framework' have been achieved by around a third of the respondents. The outcome of improved standards has been achieved by a quarter of the respondents.

Different barriers impede project uptake to a varying degree, limited financial resources being the biggest obstacle followed by an impeding legal framework. It is positive that even for these two barriers the share of respondents hardly exceeds 25%.

The huge majority of respondents think that **dissemination, exploitation and communication** activities have been both useful (76% to a large and very large extent) and sufficient (66%).

EU added value

The main recognition of the EU value added lies in the fact that three-quarters of the respondents considered that without EU funding the project would not have been implemented or, if implemented, the scope would have been reduced. Naturally, in some cases, the project would have been funded at a later stage.

Moreover, respondents consider that H2020 projects added value in a multitude of aspects to varying degrees. Aspects which stand out with above 70% of respondents answering to a large or very large extent include:

- The possibility to form multi-cultural consortia;
- The diversity of partners' profiles and coverage of various value chains;
- Providing funding opportunities for different topics; and
- Providing a good size of the project budget.

The least value-added, still above 40% large and to a very large extent, is associated with Flexibility given to respond to technological developments' and 'Flexibility given to respond to socio-economic needs' but also the 'possibility to conduct fundamental, exploratory or risky research'.

2.2. Societal Challenge 3 "Secure, clean and efficient energy"

2.2.1. Relevance and Coherence of the Intervention

Motivation for applying

One type of motivation for future applicants is related to technology and innovation considerations. The two main motivational drivers are 'Addressing specific scientific or technical questions, problems and issues' (81% to a very large and very large extent) and 'Development of new processes, products and services' (72%). The factors that matter the least were 'Accessing funding for seed research' (41%) and 'Development of non-technological innovations' (41%). Nevertheless, they remain tangible motivational drivers.

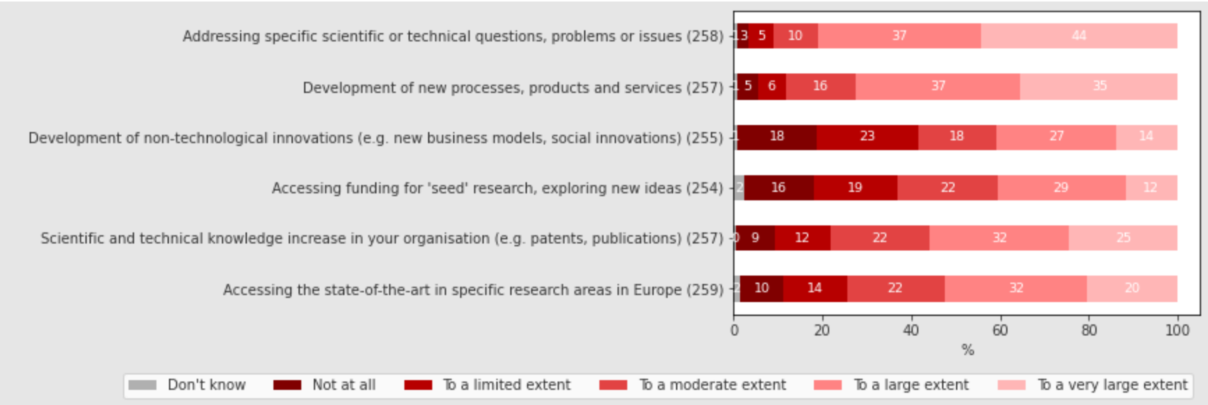


Figure 77 Q7: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 3 "Secure, clean and efficient energy"? Technology and innovation.

Climate and environment are another set of motivational drivers for applicants. The two main motivational factors are 'Contribution to development that avoids GHG emissions' (82%) and 'Addressing grand societal challenges related to the climate' (79%). The factors that matter the least were 'Reduction of the environmental impacts of the organisation' (33%) and 'Increasing resource efficiency of processes in your area' (65%). Nevertheless, they remain tangible motivational drivers.

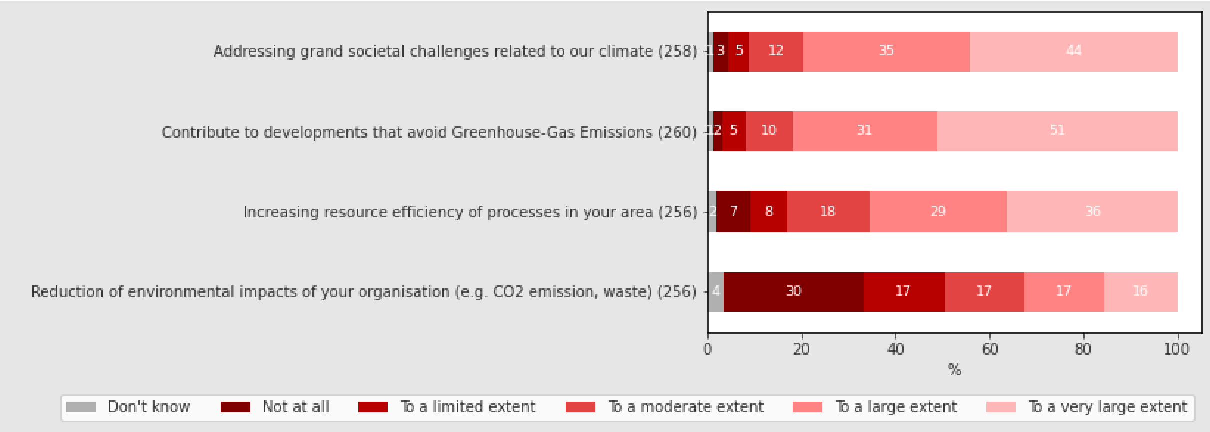


Figure 78 Q8: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 3 "Secure, clean and efficient energy"? Climate and environment-related.

Business development and competitiveness have been identified as key motivations for applicants. The biggest share of applicants was driven by a motivation to increase the visibility of the organisation (58% to a large and very large extent). This driver is followed by the 'Increase of productivity and competitiveness of the organisation (49%) and 'Diversification of the organisation activities' (32%).

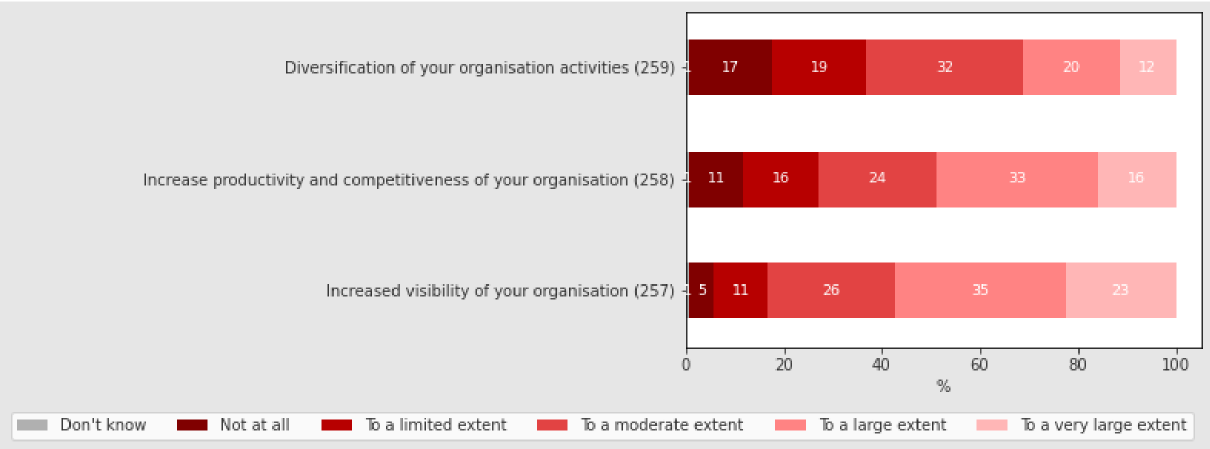


Figure 79 Q9: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 3 "Secure, clean and efficient energy"? Business development and competitiveness.

Collaboration is a major driver for participation in H2020 projects. Organisations were mainly willing to collaborate with other types of organisations (79% agree to a large and very large extent). Supposedly, this is an implicit acknowledgement of the value of the ecosystem as a whole. 'Development of non-EU collaborations' is less of a driver with 39% of the respondents for which it matters to a large and very large extent. 'Sharing a risk of a project' is the weakest of the three collaboration-related drivers (33% to a large and very large extent) but remains relevant.

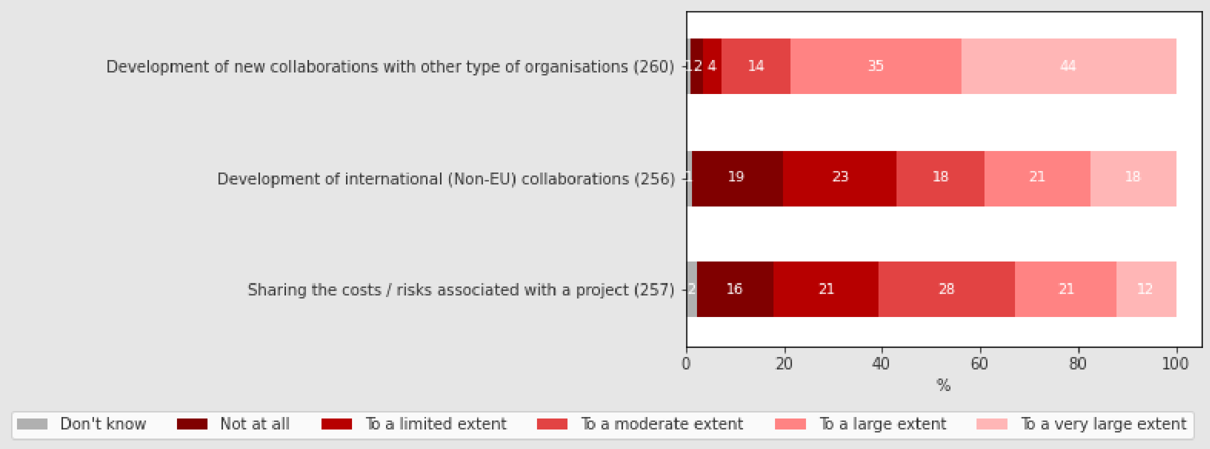


Figure 80 Q10: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 3 "Secure, clean and efficient energy"? Collaboration.

Needs and challenges

Between 14% and 70% of the respondents consider that their different needs and challenges have been addressed by the project to a large and very large extent. The challenge and needs which have been addressed to the highest extent are 'reduce energy consumption and carbon footprint' (70%), followed by 'develop low-cost, low-carbon energy technologies' (58%) and 'foster the smart integration of renewable energy' (56%). The challenges and needs which have been addressed to the lowest extent are 'develop a single smart European electricity grid' (14%) and 'make alternative fuels and energy sources more competitive' (34%).

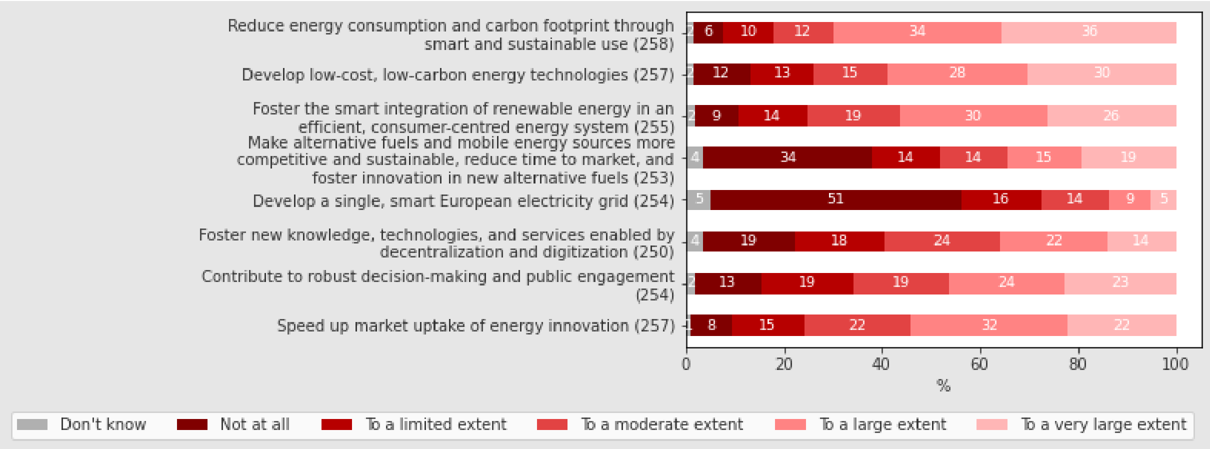


Figure 81 Q11: To what extent does your project address the following needs and challenges?

Collaboration

As pointed out previously, collaboration is a main motivational driver for H2020 participants. While the previous question was referring mainly to collaboration within the consortium, the one below targets collaboration with organisations outside the consortium. The intensity of collaboration was by far the highest with regards to research organisations (48% collaborated or co-led) followed by High Education Institutions (HEI) (41%). The lowest level of collaboration intensity was identified with regard to Research Funding Organisations (10%) and NGOs (19%).

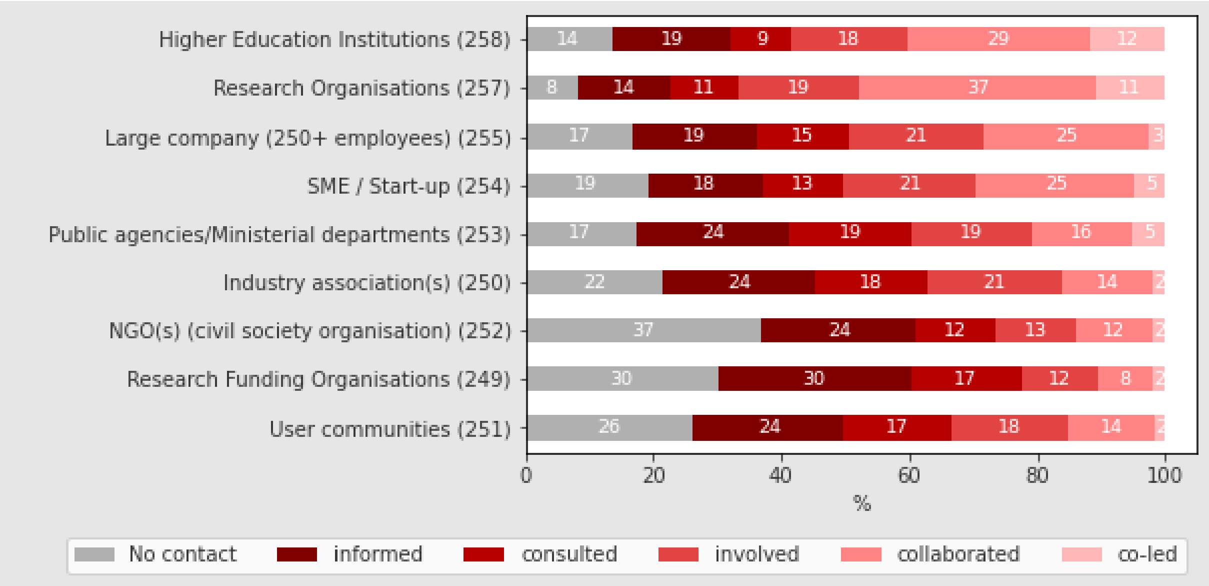


Figure 82 Q12: How intense was your collaboration with the following stakeholder groups outside the project consortium in the context of your project?

An overwhelming majority of 71% of the respondents believed that all relevant stakeholder groups were addressed through the project activities. By responding ‘Partially’ (27%) or ‘Not at all’ (2%) the remaining respondents believed that improvements were possible. Some of the recommendations for improvements are summarised after the table.

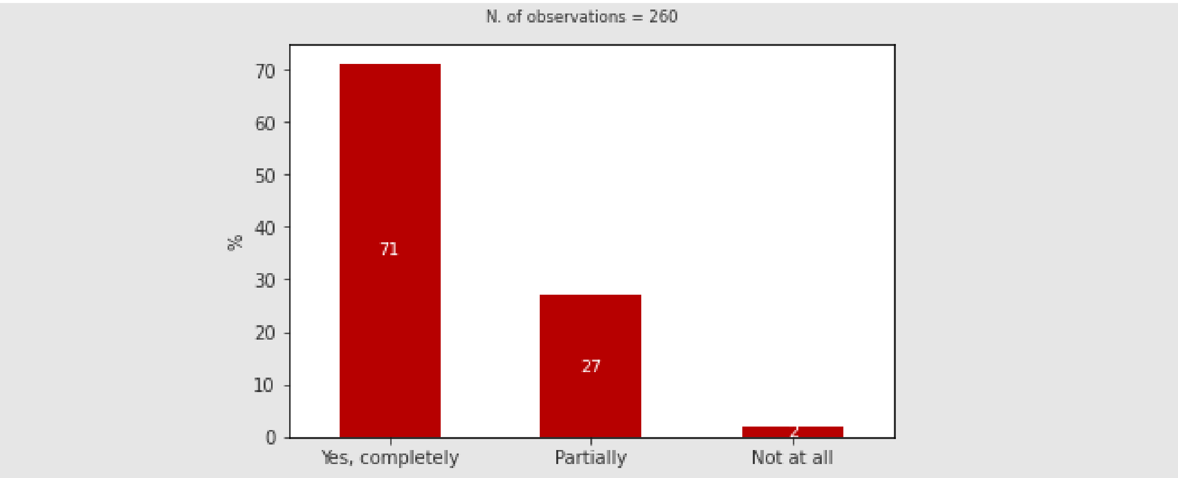


Figure 90. Q13: In your opinion, were all relevant stakeholder groups sufficiently addressed through the project activities?

Q14: Considerations with regards to stakeholder involvement.

- Data protection concerns hindered information exchange between stakeholders and therefore their engagement in some cases.
- Engaging all stakeholders to an equal extent proved to be difficult. These difficulties vary from project to project, but civil society or 'consumer' engagement is recurringly mentioned to be challenging.
- Stakeholder engagement is dependent on the time and resources at hand. The engagement of some stakeholders is more time-consuming which possibly explains the afore)mentioned discrepancy.
- Respondents illustrate a range of successful activities to involve stakeholders in their project. Such are for example online workshops, public events, webinars, or citizen panels.
- It is necessary to align stakeholder engagement well with the needs of a project. Respondents with a well-considered and continuously updated engagement strategy emphasised their success. In some cases, such strategies can e.g., include a successive intensification of involvement.

- Other respondents see a high level of stakeholder engagement as a general hindrance to efficiency. They note that poorly targeted engagement can be counterproductive and stress that stakeholder engagement should not be an end in itself.
- It is beneficial to identify relevant stakeholders via existing networks. For example, different countries involved maintain good contacts within their countries.
- In some cases, a lack of interest on the side of stakeholders proved a hindrance.
- The ongoing Covid19 pandemic made stakeholder engagement more difficult, e.g. online events were found to be less engaging. In some cases, this disallowed projects to pursue their existing engagement plans.

In addition, it should be pointed out that 27% of these respondents indicated that they have collaborated with non-European partners within the project.

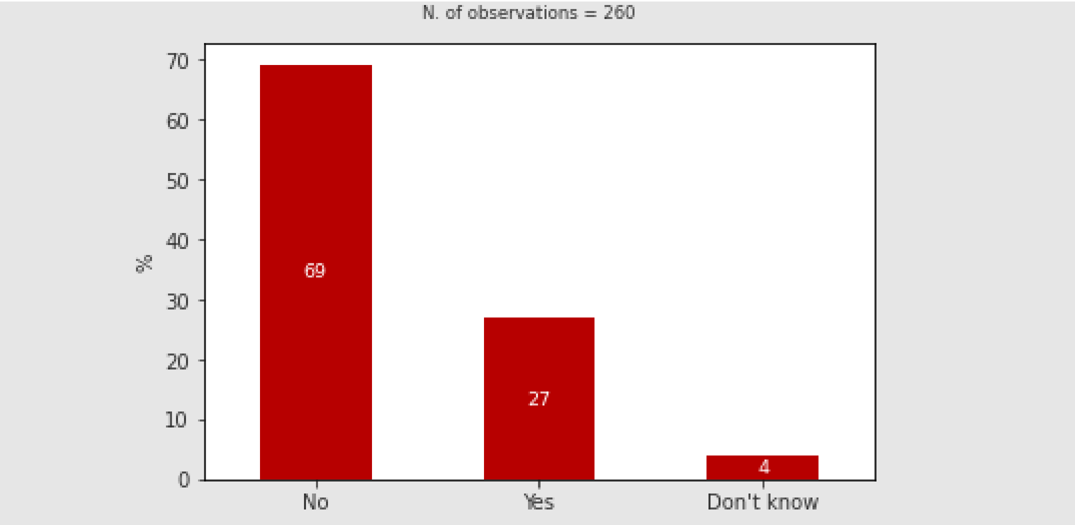


Figure 91. Q15: Have you collaborated with non-European partners as project partners in your project?

Those who collaborated with non-European partners pointed to several major benefits of this collaboration. 'Development of know-how' is the biggest identified benefit (75% - to a large or very large extent) followed by 'Development of new, additional partnerships' (63%). 'Access to new markets' and 'Reduction of the environmental impact of the organisation' have been the two smallest benefits (17% and 22% respectively).

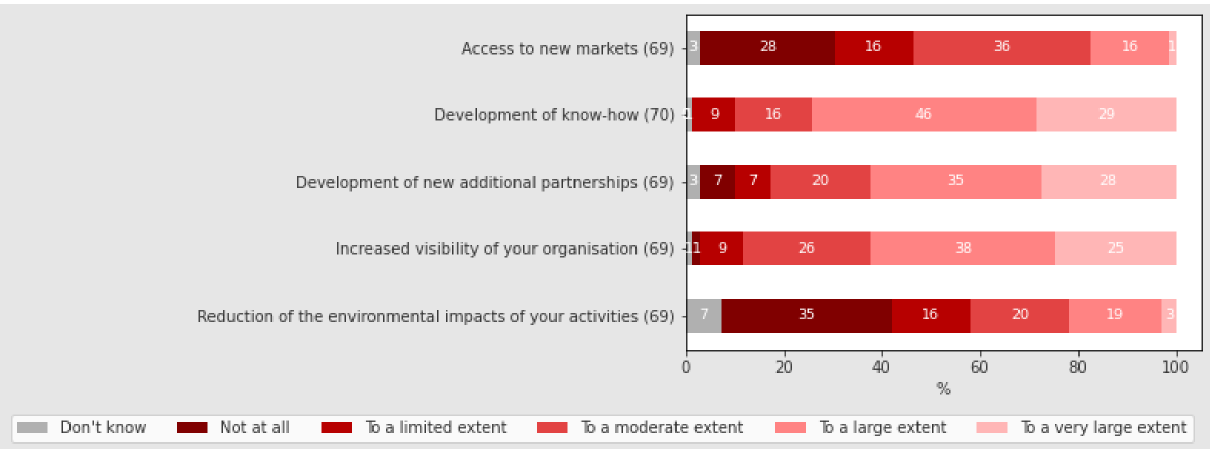


Figure 83 Q16: To what extent have you experienced the following benefits from the international cooperation in your project?

It has to be pointed out that some 37% of the respondents consider that cooperation with non-European partners contributes to a large or very large extent to improving the European position in the global competition. Some 21% think this advancement is to a moderate extent. Some 23% think it is either to a very limited extent or not at all while the remaining 19% either don't know or think it is too early to tell.

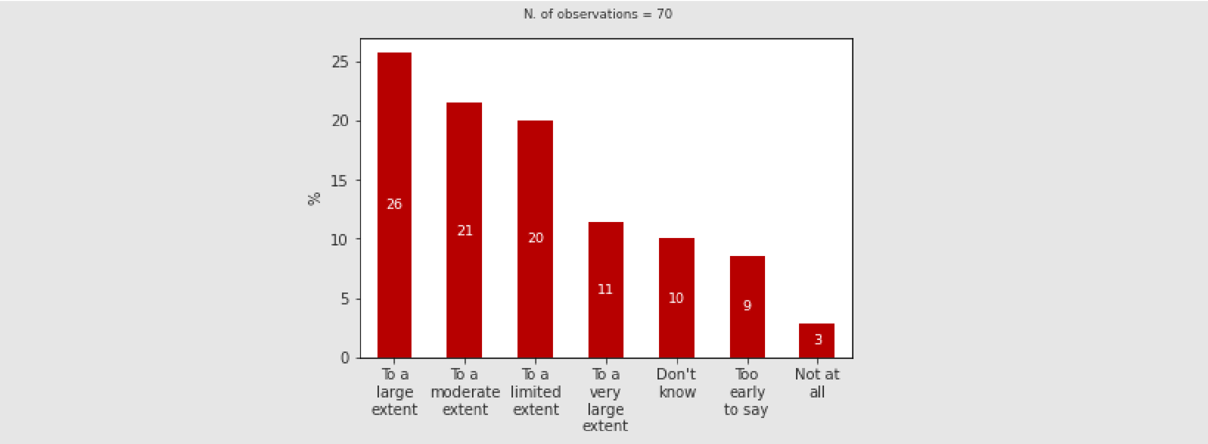


Figure 84 Q17: Has the cooperation with non-European partners in H2020 contributed to improving the European position in the global competition?

2.2.2. Effectiveness of the intervention

Results of the intervention

The answers to the survey revealed a high level of alignment between the objectives of the projects and their results. Some 87% of the respondents considered that these are fully aligned or aligned to a large extent. For 2% of the respondents, they are aligned to a limited extent.

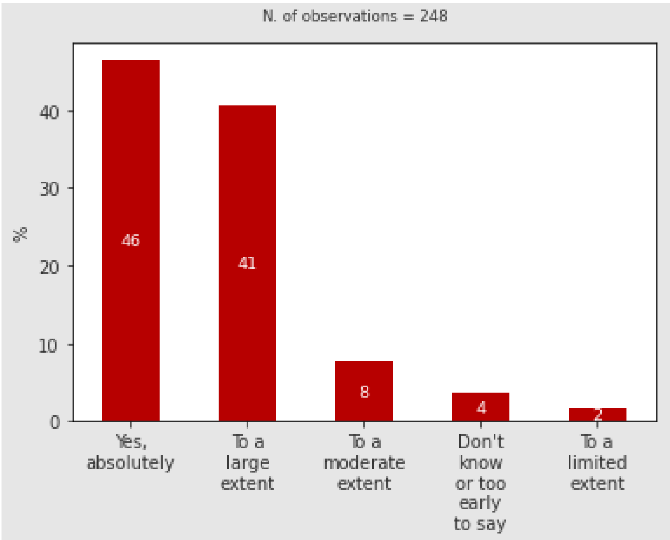


Figure 85 Q6: Are the results of your project in line with its objectives?

Between 30% and 69% of the respondents assess that the project contributed to a large or very large extent to the improvement of different aspects of expertise.

'Contribution to knowledge and capacity building' and 'Contribution to scientific and technological development' stand out as the aspects of expertise which have been improved to a large or very large extent (69% and 59%).

'Contribution to market and business development' and 'Contribution to policy making and standard setting measures' are the expertise components which have been improved the least as only 29% and 32 % of respondents consider that it has been improved to a large or very large extent.

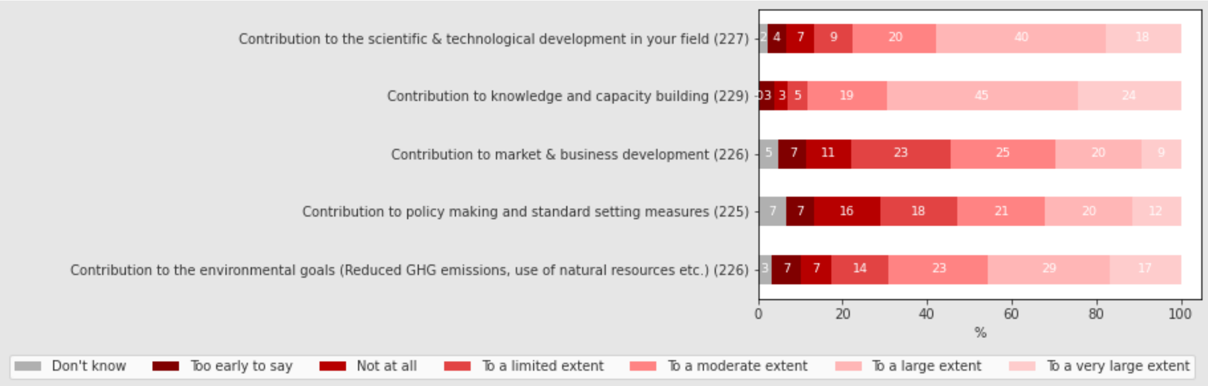


Figure 86 Q29: How successful was your project in terms of contributing to the following dimensions in your area of expertise:

Scientific results

Between 49% and 79% of the respondents assess that different scientific results have been fully achieved or achieved to a large extent. ‘Better understanding of the subject’ stands out as the scientific result which has been achieved to the highest extent (79%). It is followed by ‘Publications in peer-reviewed journals’ (58%) and 'Better access to state-of-the-art research' (53%). There is no (anticipated) scientific result which stands out with a low extent of achievement, the lowest being 'Researchers trained' with 49%.

Figure 87 Q18: In terms of scientific outputs, what are the (anticipated) results of your project?

Technology and Innovation

Between 22% and 62% of the respondents assess that the technological development results have been fully achieved or achieved to a large extent.

'New research tools, models, simulations' and 'Expansion of basic knowledge for technological development' stand out as the technological developments results which have been achieved to the highest extent (62% and 59%).

'Increasing the safety of technologies and components' (22%) and 'Cost reduction of technology' (26%) are the anticipated technological development results which stand out with a low extent of achievement (full or to a large extent).

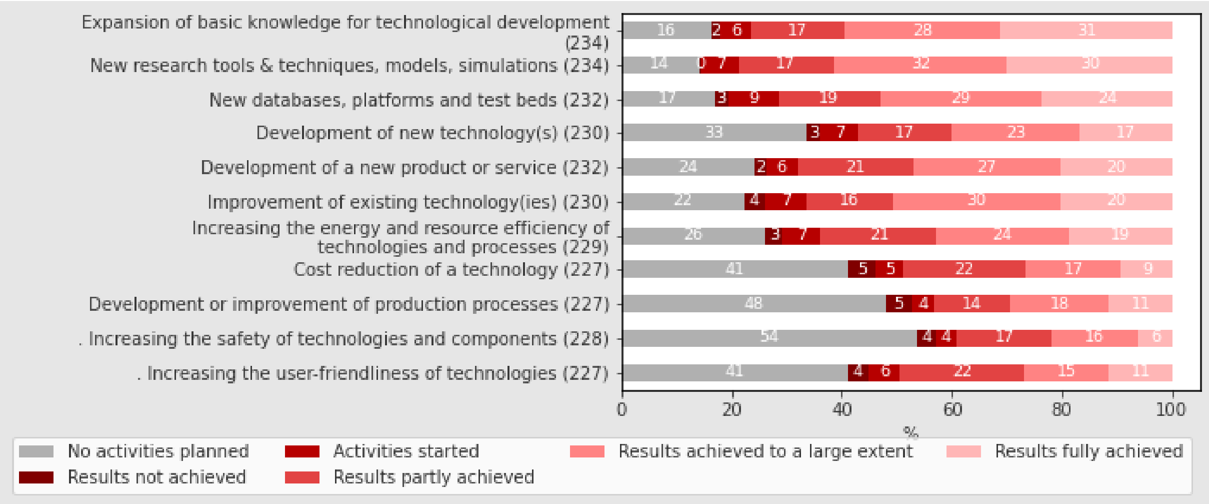


Figure 88 Q19: In terms of technological development outputs, what are the (anticipated) results of your project?

In terms of the contribution of the project to H2020 desired outcomes in Technology and Innovation, the respondents identified 'Solutions across technology fields and sectors' as the biggest achievements (45% think that their projects contributed to this outcome to a very large or large extent). On the other side of the spectrum, the outcomes achieved to the least extent are 'Affordable and integrated energy storage solutions' (19%) and 'Digitalisation of the energy system' (20%).

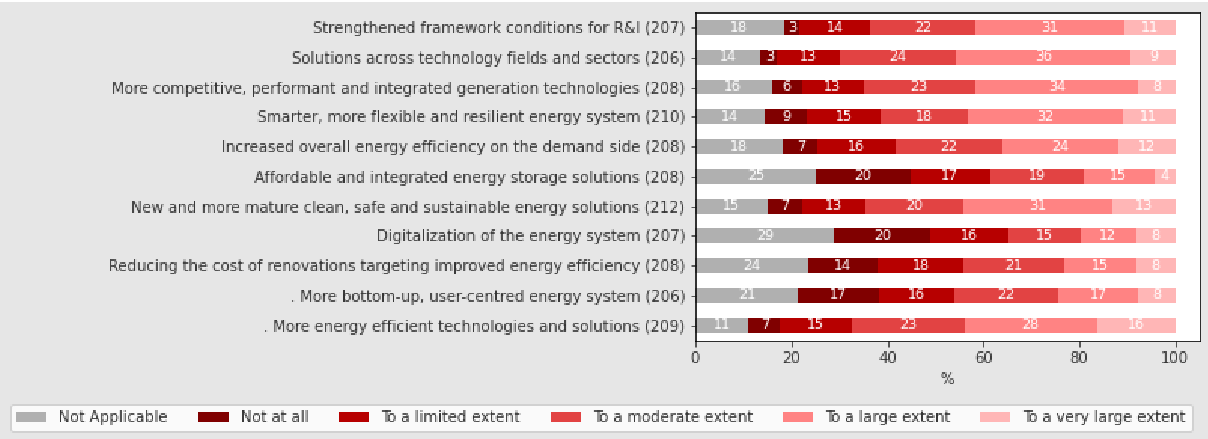


Figure 89 Q30: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Technology and Innovation

Between 14% and 47% of the respondents assess that the system development results have been fully achieved or achieved to a large extent.

'Demonstration or pilot feasibility of technological solutions' and 'Integration of technology' are the system development results which have been achieved to the highest extent (47% and 40%).

'Developing innovations in marketing and sales' (14%), 'Developing of social innovations' (19%) and 'Contribution to the development of new norms and standards' (22%), are the anticipated market development results which stand out with a low extent of achievement (full or to a large extent).

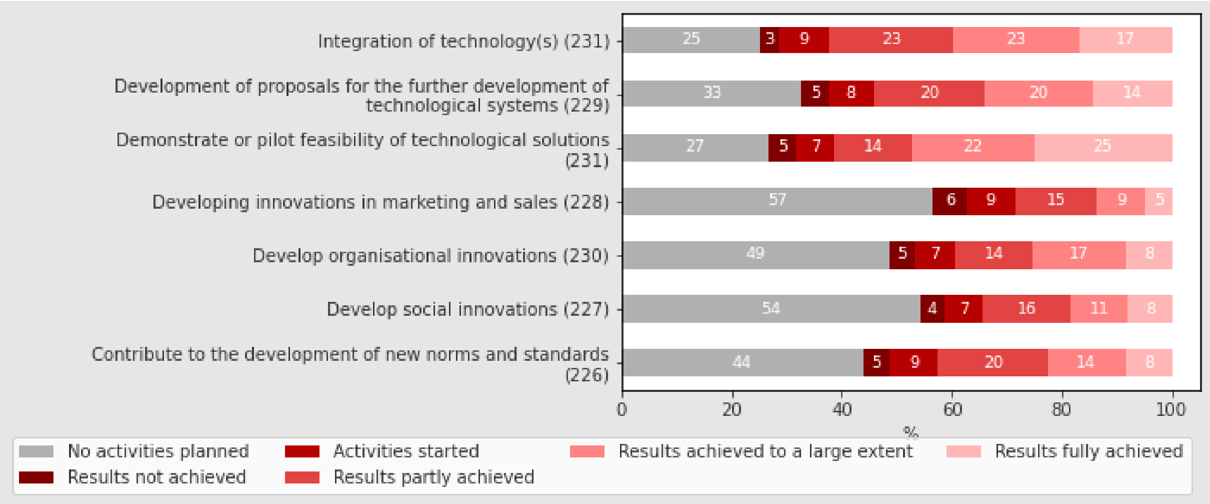


Figure 90 Q21: In terms of system development, what are the (anticipated) results of your project?

The TRL concept has not been considered relevant by almost one-third of the respondents (29%). Initially, almost one-fifth of the respondents (19%) considered their overall TR level as TRL 4 followed by TRL 3 (17%) and TRL 2 (12%). An insignificant number of projects considered their TRL level 1, 7, 8, 6 or 9.

Data does not allow comparison between TRL levels at the start and the end of the same project. Nevertheless, given that the number of TRL 2 and TRL3 projects went down significantly, it could be said with high probability that some of the projects moved up to TRL5, 6, or 7.

An additional analysis was done regarding the distribution of types of actions. This showed that for the highest percentage of CSA projects, the TRL was not applicable. IA projects, however, showed the highest percentage of projects were in high TRL stages. RIA projects were predominantly in slightly high TRL levels.

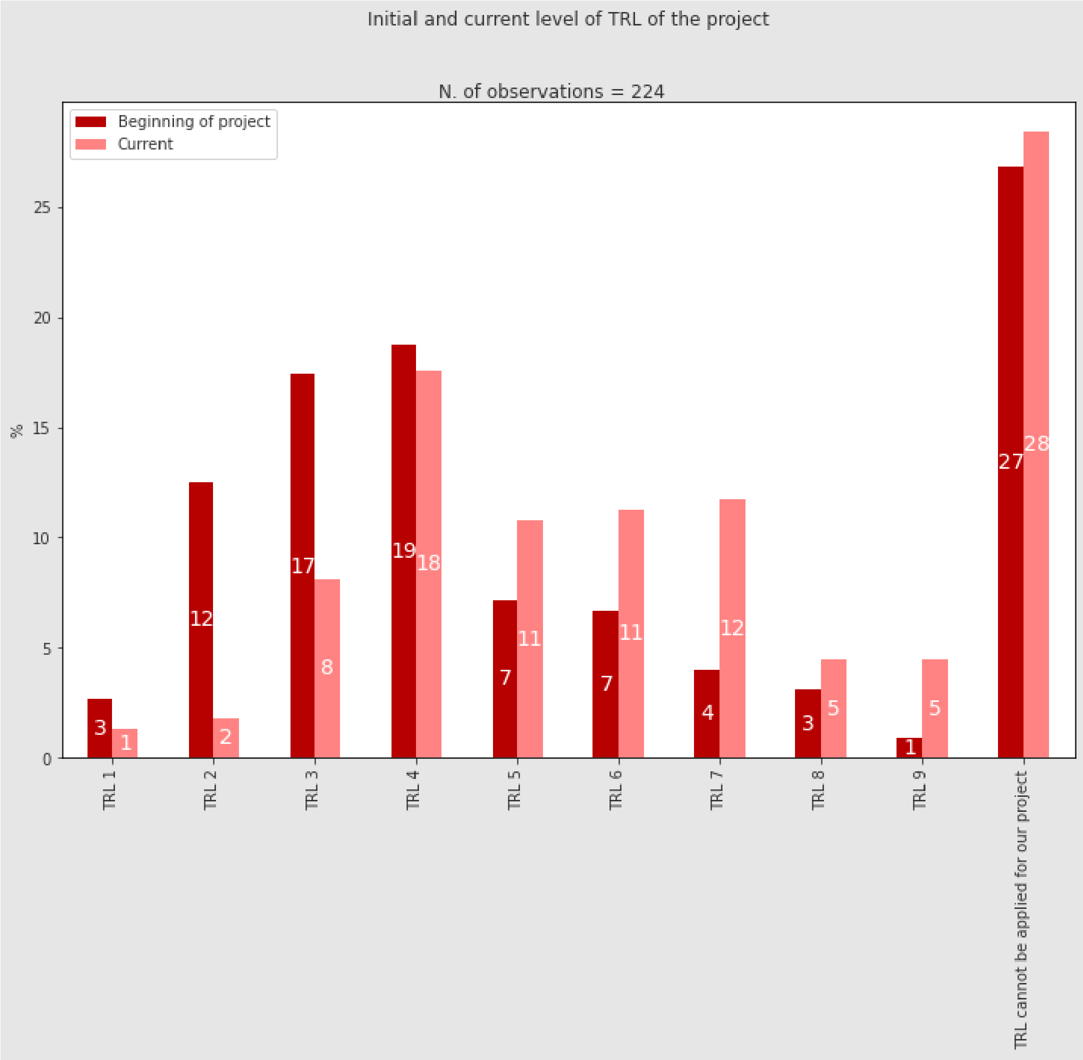


Figure 100. Q22: What was the overall level of Technology-Readiness at the beginning of the project (TRL)? And Q23: What is the current overall level of Technological-Readiness of your project's technological development?

In addition, it should be noted that TRL 4 is the most common target TRL level with 29%. Followed by TRL 7 (13%), TRL 5 (11%) and TRL 6 (10%). Again, most respondents indicated that the TRL concept cannot be applied to their project (29%).

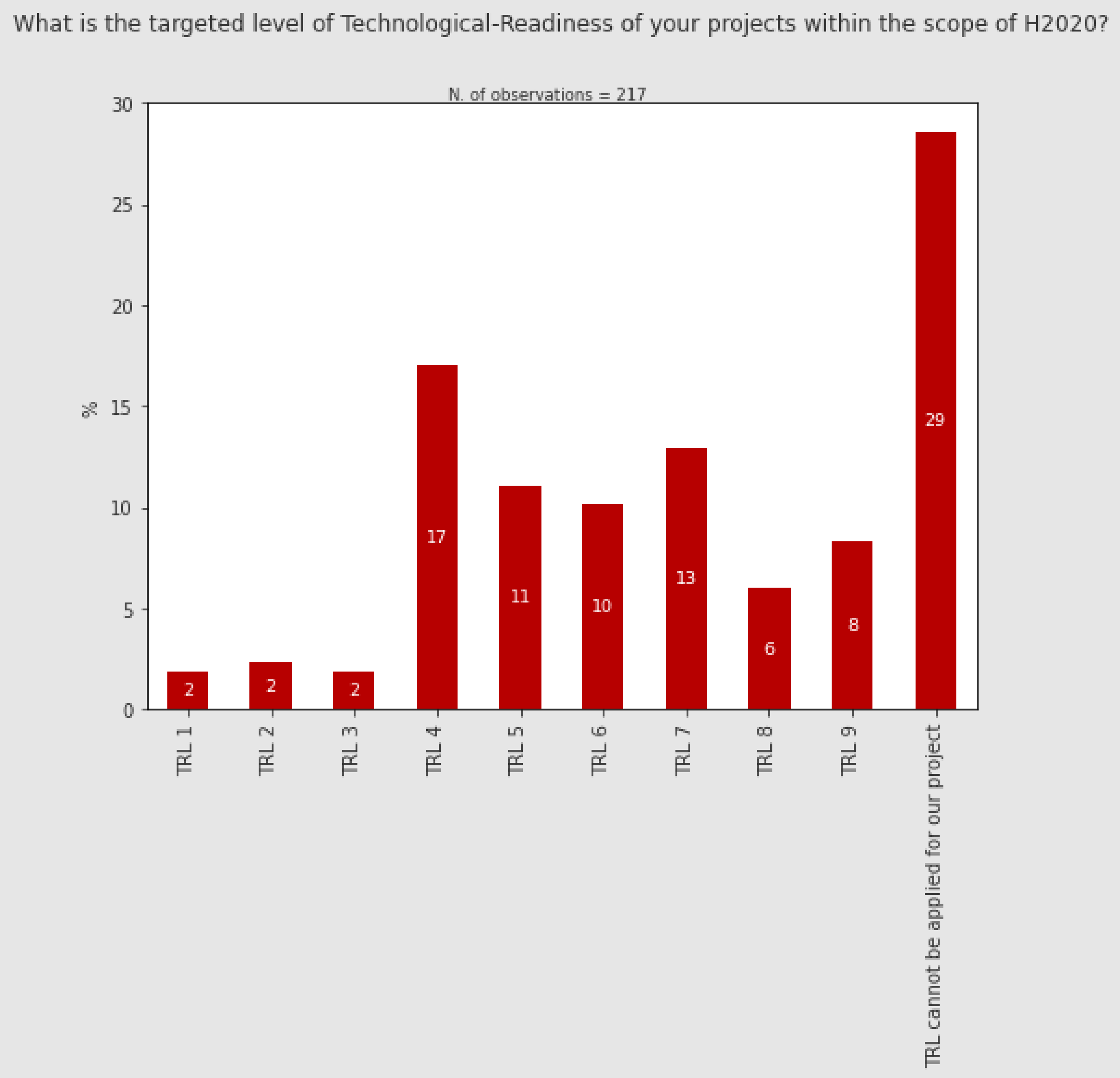


Figure 101. Q24: What is the targeted level of Technological-Readiness of your projects within the scope of H2020?

Knowledge and Capacity

Between 20% and 48% of the respondents assess that the project influenced their organisation to a large or very large extent with regard to different organisational aspects.

'Intensified collaboration on R&D with new organisations' and 'Increased focus on interdisciplinary research' are the two aspects which the project has influenced most (48% and 46%, to a large and very large extent).

'Increased focus on risk-oriented research', is the aspect of the organisation which stands out as only 20% of the respondents thought it had been influenced to a large or very large extent.

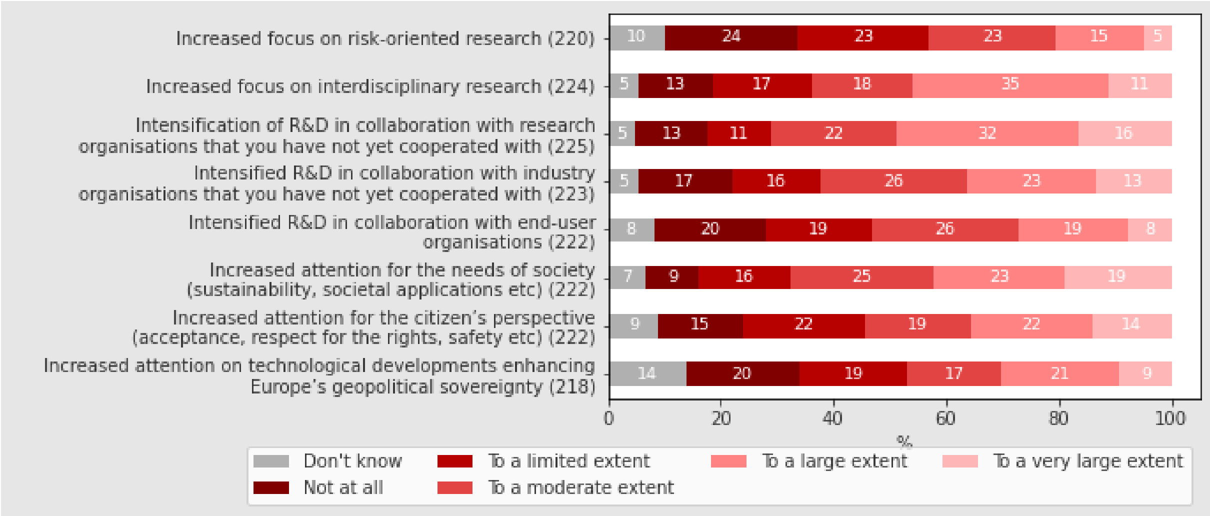


Figure 91 Q26: To what extent did your project influence the following aspects of your organisation?

With regard to the contribution of the project in terms of enabling several desired outcomes. 'Strengthening R&I capacities in your area' and 'EU excellence in science and innovation' stand out as the two outcomes achieved to the largest extent (50% and 47% respectively). The two desired outcomes which have been achieved to the lowest extent are the 'Creation of world-class European research facilities' (23%) and 'Improved attractiveness of researcher's careers across the EU' (28%).

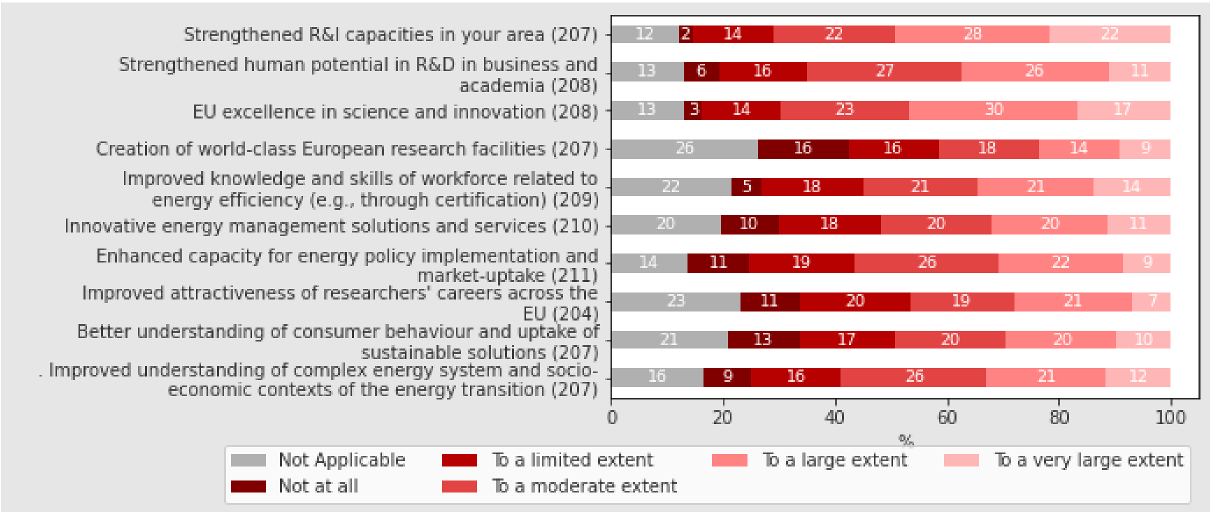


Figure 92 Q31: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Knowledge & Capacity.

Coordination and collaboration

Between 20% and 52% of the respondents considered that their projects contributed to the different desired outcomes of Horizon 2020. 'International cooperation and networks address common challenges and explore synergies' is the outcome most affected with 52% of respondents considering the contribution to be to a large or very large extent. 'Stronger involvement of civil society in R&I' stands out as the outcome to which projects have contributed the least (20%, to a large or very large extent).

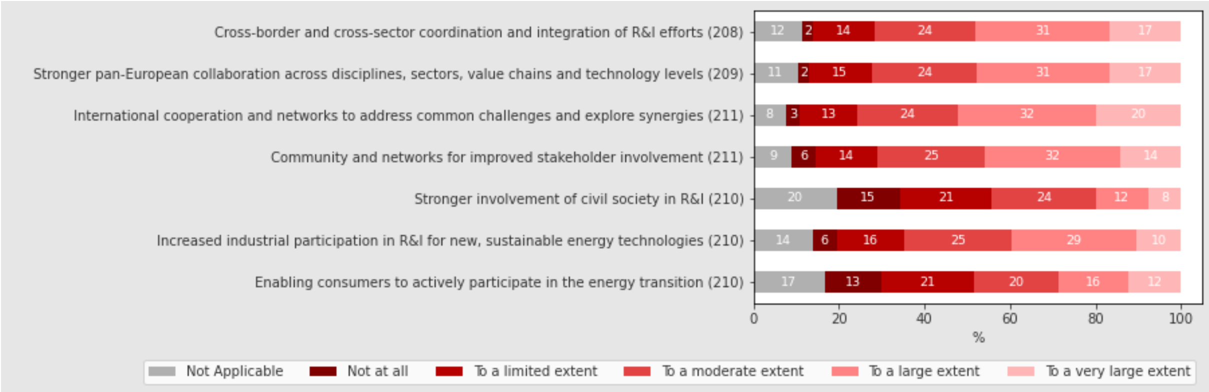


Figure 93 Q32: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Coordination & Collaboration.

Markets and business

Between 2% and 36% of the respondents assess that the market development results have been fully achieved or achieved to a large extent. 'Development of marketable products or services' and 'Market launch of new products/services' are the market development results which have been achieved to the highest extent (36% and 28% respectively). 'Creation of a start-up' and 'Creation of a spin-off', are the anticipated market development results which stand out with a low extent of achievement (full or to a large extent) (2% and 4% respectively).

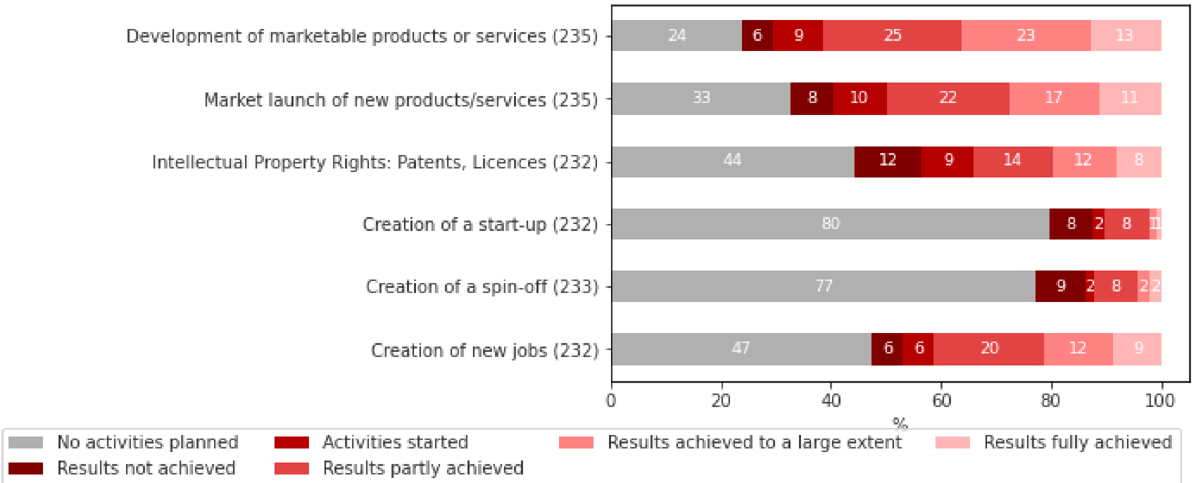


Figure 94 Q20: In terms of market development, what are the (anticipated) results of your project?

Some 38% of the respondents think that the project has contributed to a large or very large extent to the improvement of time-to-market of technological solutions. Inversely, 20% consider that this has happened to a limited extent (12%) or not at all (8%).

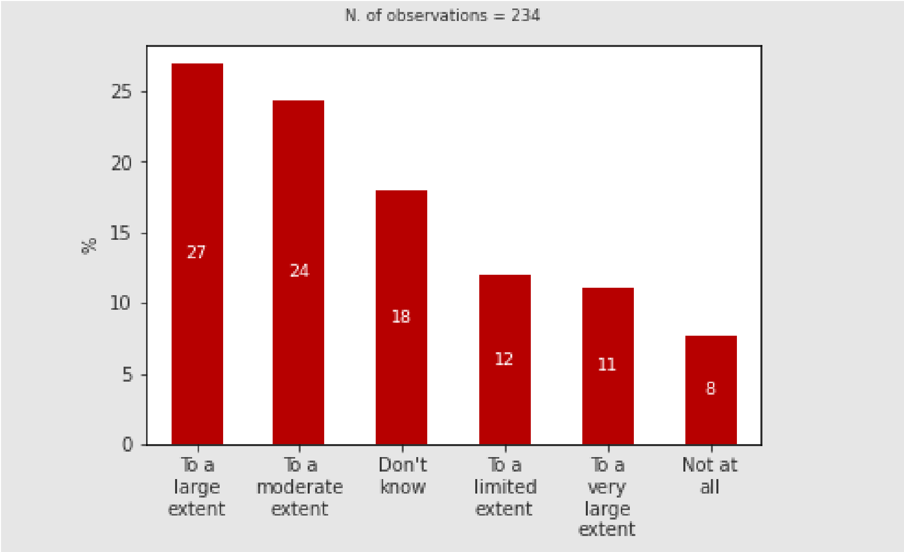


Figure 95 Q25: Has the project contributed to improve the "time-to-market" of new solutions?

No more than 11% of the respondents consider that the project led to a 20% or more increase in turnover, employment or profit. Between 5% and 11% of the respondents think that there has been an incremental increase between 11% and 20% for these three aspects. Between 20% and 31% of the respondents think that there has been an incremental increase between 1% and 10% for these three aspects. Between 49% and 70% of the respondents either don't know if there has been an increase in these three aspects or think that there has been no change.

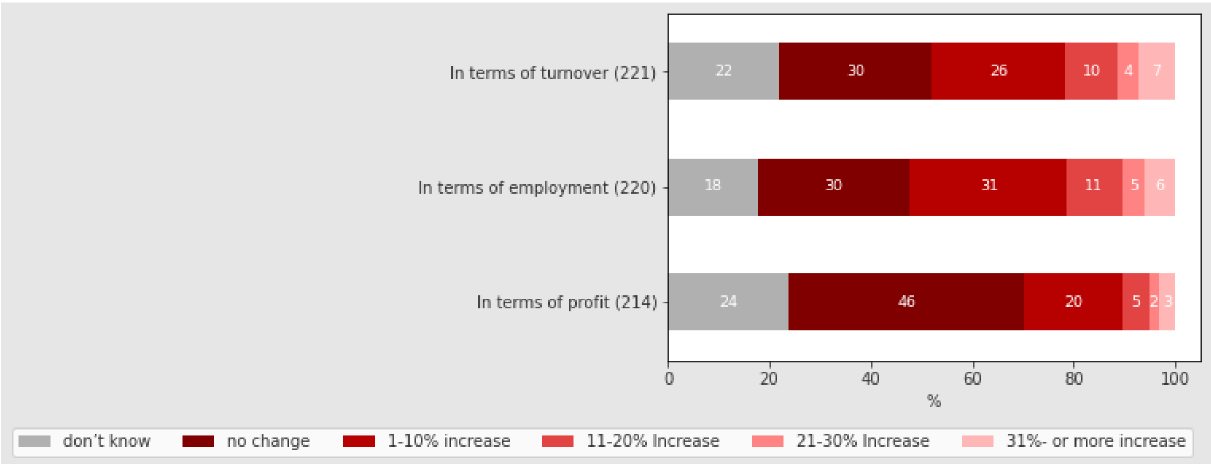


Figure 96 Q27: To what extent has your participation in H2020 led to the following economic benefits (or is it expected to do so after project completion) in your operational unit? Please provide best estimates.

Between 28% and 44% of the respondents assess that the project influenced their competitiveness nationally (45%), in Europe (39%) or internationally (28%) to a large or very large extent. Around 24-25% think that the increase has been to a moderate extent. Between 20% and 32% of the respondents either 'don't know or it is too early to say' or think that the project influenced their competitiveness nationally, in Europe or internationally not at all or to a very limited extent.

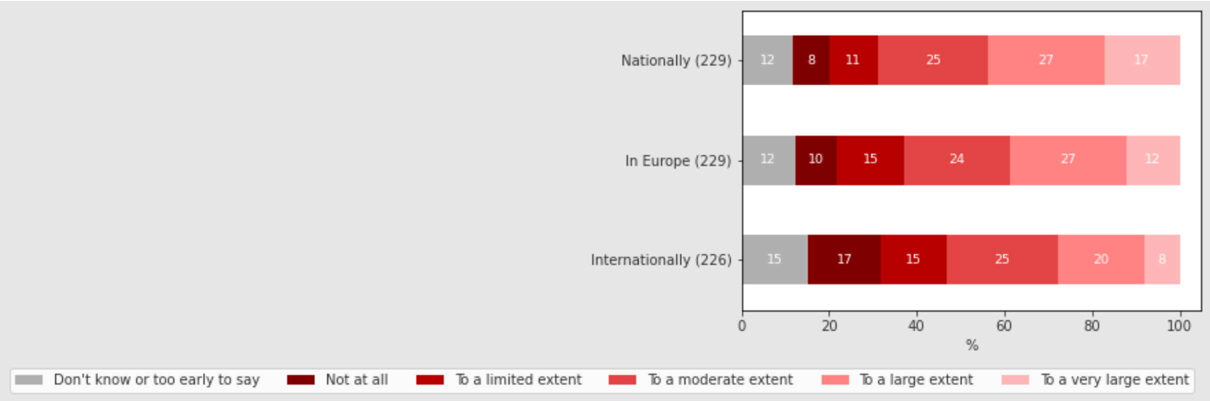


Figure 97 Q28: Do you consider that your project contributed to the increase of the overall competitiveness of your operational unit?

Between 16% and 34% of the respondents think their project contributed to a large or very large extent to the different desired outcomes. The share is the highest for the outcome ‘More competitive energy system’ (36%) followed by ‘Increased market-uptake of innovative, resource efficient solutions’ (34%). The share is the lowest for the outcome ‘More investment through stronger private capital in energy efficiency’. It must be noted that a significant portion of the respondents think the contribution has been moderate (19-29%). If they are taken into consideration ‘Higher consumer awareness and acceptance’ comes second.

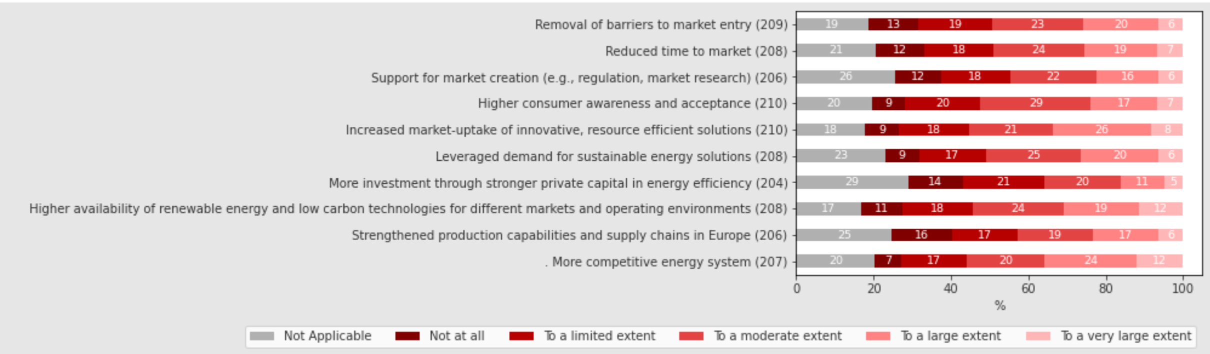


Figure 98 Q33: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Market & Business.

Policies and standards

Between 16% and 27% think the projects contributed to the desired outcomes in terms of policies and standards. ‘More robust and transparent policy-making products’ comes first with 27% of the respondents while ‘Harmonisation in calculation of energy performance and certification’ and ‘New and/or improved standards for interoperable networks, new technologies and services’ come last with 16% and 20% respectively.

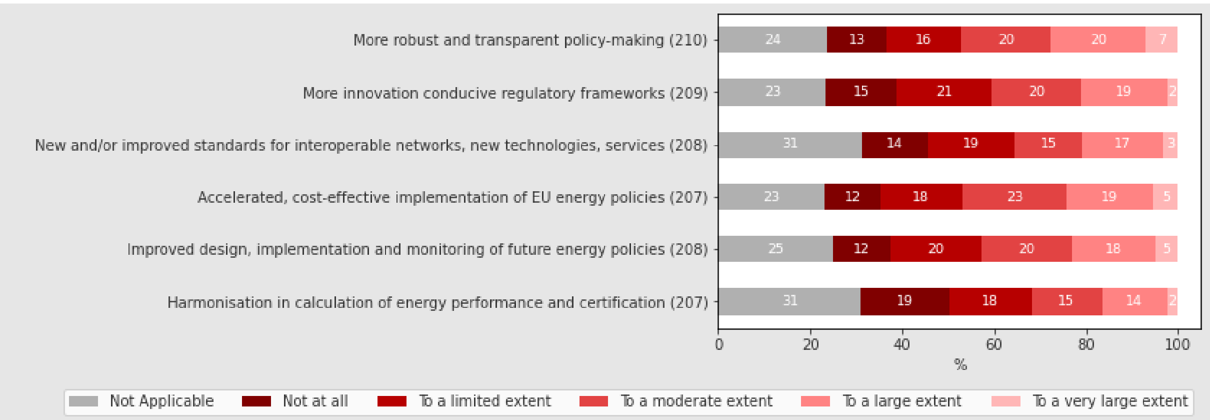


Figure 99 Q34: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Policies & Standards.

Barriers and enabling factors

Between 12% and 36% of the respondents consider that different types of barriers impede the successful uptake of their projects. The two barriers which stand out are ‘Limited financial resources for the implementation of project results’ (36%) and ‘High economic risk’ (25%). If respondents who chose that the influence is moderate are added to the figures, then ‘Impeding legal framework’ and ‘Burdensome licensing procedures and administrative processes’ are also tangible with 45% and 43% respectively. Overall, all the mentioned barriers are valid.

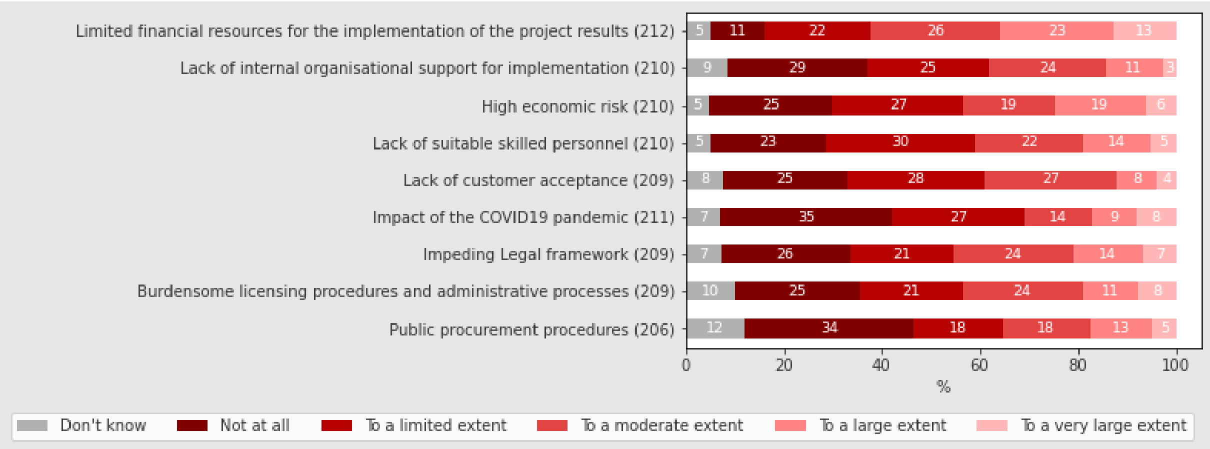


Figure 100 Q35: Barriers and enabling factors: Do you see barriers that impede a successful uptake of results of your project?

Dissemination, exploitation and communication

The overwhelming majority of respondents think that dissemination, exploitation and communication activities have been both useful (72% to a large and very large extent) and sufficient (65%). Only 13 % don’t know or consider that they have been neither useful nor sufficient.

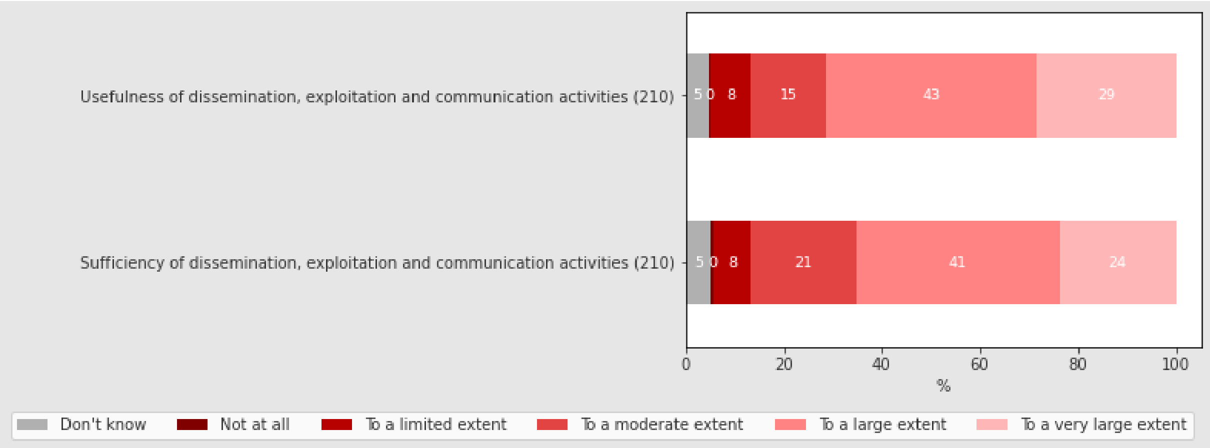


Figure 101 Q36: To which extent have the dissemination, exploitation and communication activities been useful and sufficient in the uptake of your project results?

2.2.3. EU added value

Between 34% and 76% of the respondents think that H2020 provided an EU-added value in several aspects to a large and very large extent. The aspects of 'Multi-cultural consortia' and 'Diversity of partner profiles' come first, both with 76%. They are followed by 'Funding opportunities for specific topics' (73%). The lowest value added is on 'Flexibility given to respond to changing socio-economic needs' (34%) and 'technical support provided' (37%).

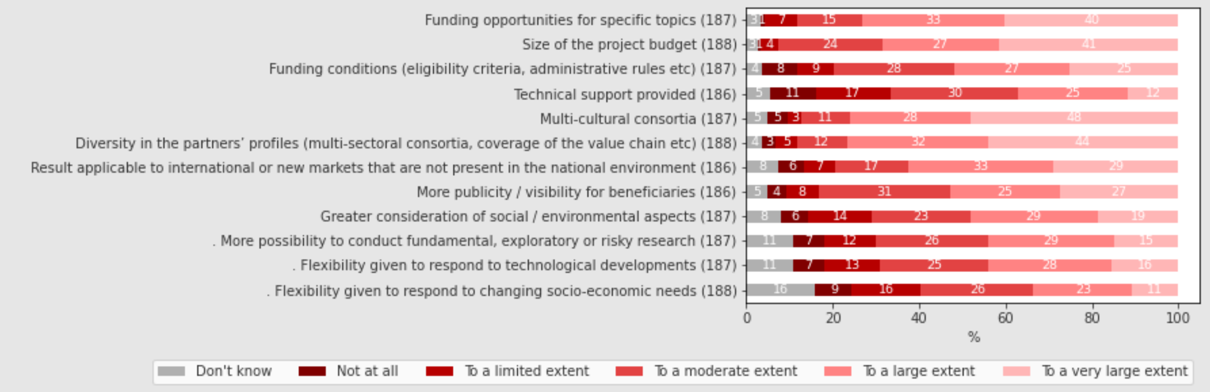


Figure 102 Q50: To what extent do you see added value from funding Horizon 2020 projects compared to funding on a national or regional level?

Some 71% of the respondents answered that, without support from Horizon 2020, the project would not have been implemented; 75% - the scope would have been reduced; 44% that it would have been implemented with other partners; 17% that it would have been funded on a national or regional level; 30% that its timeline would have been extended; and 42% that it would have been delayed.

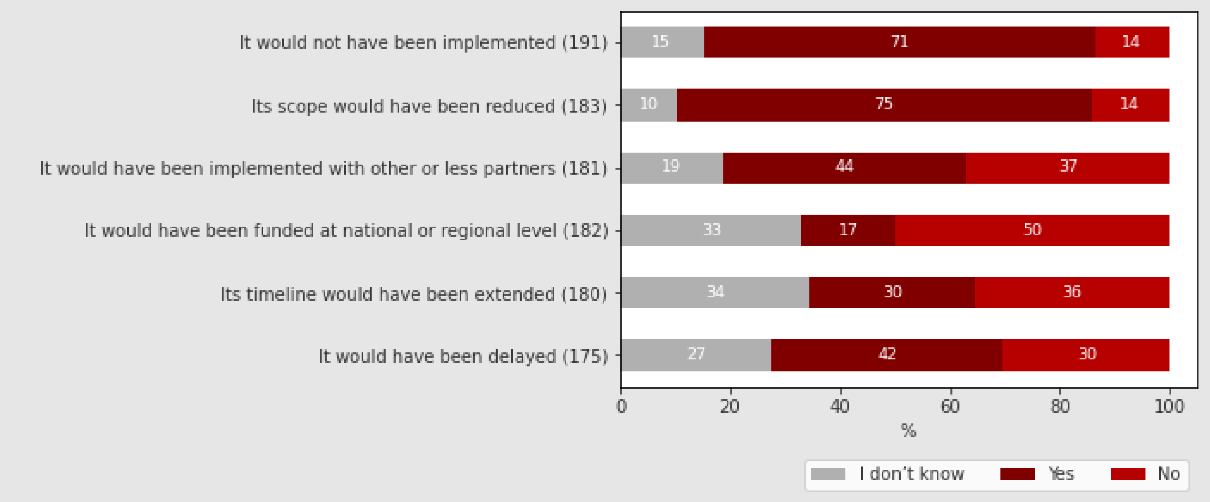


Figure 103 Q51: Without support from H2020, what would have happened to your project?

2.2.4. Summary

Relevance and coherence

In terms of technology and innovation, the two main **motivational drivers** for respondents are 'addressing specific scientific or technical questions, problems and issues' and 'development of new processes, products and services'. 'Accessing funding for seed research' and 'Development of non-technological innovations' did not appear to be of the same importance. As far as climate and environment are concerned, 'Contribution to development that avoids GHG emissions' and the need 'to address grand societal challenges related to climate' were the biggest motivators for participation in the Framework Programmes. From a business and competitiveness point of view, 'increasing the visibility of the organisation' exceeded significantly other motivational factors such as 'increasing the productivity and competitiveness of the organisation' and 'diversification of the organisational activities. Collaboration is a strong driver for participation in FPs, especially the 'development of new collaborations with other types of organisations' and much less so 'developing collaborations with non-EU organisations' and 'sharing the risks of a project'.

The needs and challenges of projects have been addressed to varying extents. *'Reducing energy consumption and carbon footprint'* has been addressed to the highest extent. The challenges and needs which have been addressed to the lowest extent are *'developing a single smart European electricity grid'* and *'making alternative fuels and energy sources more competitive'*.

Collaboration is key for H2020 projects and its intensity was the highest with *Research Organisations* and *Higher Education Institutions* which exceeded by far collaboration with other types of stakeholders. On the other end of the spectrum, collaboration was lowest with *Research Funding Organisations* and *NGOs*.

With regards to **involving stakeholders** in the work of the projects, 71% of respondents believed that all relevant stakeholder groups were addressed. 27% considered this was done only partially. Identified reasons for this are diverse, ranging from the effects of Covid-19 to lacking time and resources or disinterest on the stakeholder side. A coherent and continuously updated stakeholder engagement strategy has proven to be a remedy according to some respondents. **Collaboration with non-EU partners** took place for roughly a fourth of the respondents but those who collaborated saw benefits from it the main one being *the 'development of know-how'*. *'Access to new markets'* has not been identified as a major benefit. Respondents are split with regards to the contribution of cooperation with non-EU partners on European position in the global competition: More than one-third considered this to be the case to a large and very large extent; roughly a fifth thought the impact was moderate, while the remaining respondents are either sceptical, convinced otherwise or do not know.

Effectiveness

According to survey responses, there is a high level of alignment between project objectives and results. From a **knowledge** perspective, the project contributed to the largest extent to *'knowledge and capacity building'* and *'scientific and technological development'*. The *'Contribution to market and business development'* has been the lowest. In terms of **scientific results**, respondents consider that the project contributed to the largest extent to a *'better understanding of the subject'* and *'publications in peer reviewed journals'.*

With regards to **technology and innovation**, the share of respondents who consider results have been fully achieved or achieved to a large extent is lower than for knowledge- and science-related results. *'New research tools, models, simulations'* and *'Expansion of basic knowledge for technological development'* are the two technological development results which have been achieved to the highest extent. *'Increasing technology safety'* and *'Cost reduction of technology'* have been achieved to the lowest extent. In terms of **technological development outputs**, the respondents identified 'Solutions across technology fields and sectors' as the biggest achievement. On the other side of the spectrum, the outcome achieved to the least extent is 'Affordable and integrated energy storage solutions'. **System development results** are considered as achieved fully or to a large extent by no more than half of the respondents. *'Demonstration or pilot feasibility of technological solutions'* and *'Integration of technology'* are the system development results which have been achieved to the highest extent. However, social as well as marketing and sales innovations are on the low end.

The **TRL concept** has not been considered relevant by almost one-third of the respondents. The technology readiness for more than one-third of the projects was TRL2 and TRL3 at the start of the project. The overall TRL levels at the end of the projects do not reveal a significant difference although data does not allow comparison between TRL levels at the start and the end of one in the same project.

Organisational knowledge has been influenced to a large and very large extent for 20%-48% of the respondents, the largest focus being on *'intensified collaboration on R&D with new organisations'* and *'increased focus on interdisciplinary research*'. At the same time *'Increased focus on risk-oriented research'* has been influenced by only one-fifth of the respondents. Around half of the respondents validated the assumption that projects strengthened R&I capacities and EU excellence in science and innovation.

With regards to **coordination and collaboration**, no more than half of the respondents considered that their projects contributed to the different desired outcomes to a large or very large extent. '*Networks to address common challenge'* stands out as the most affected outcome while *'Stronger involvement of civil society in R&I'* constitutes the outcome to which projects have contributed the least.

Market and business were not identified as a large or very large achievement by more than one-third of the respondents. 'Development of marketable products or services' and 'Market launch of new products or services' are on the highest end while 'Creation of start-ups and spin-offs have been achieved to a large or very large extent by less than 10% of the respondents. Almost 40% think the time-to-market of technological solutions has been improved. The impact of the project on the microeconomic bottom line – turnover, employment, profit - of the project is very limited.

EU added value

The main recognition of the EU value added lies in the fact that three-quarters of the respondents considered that without EU funding the project would not have been implemented or, if implemented, the scope would have been reduced. Naturally, in some cases, the project would have been funded at a later stage.

Moreover, respondents consider that H2020 projects added value in a multitude of aspects to varying degrees. Aspects which stand out with above 70% of respondents answering to a large or very large extent include:

- The possibility to form multi-cultural consortia;
- The diversity of partners' profiles and coverage of various value chains; and
- Providing funding opportunities for specific topics.

The least value-added, still over 30% large and to a very large extent, is associated with 'Flexibility given to respond to socio-economic needs' but also the 'technical support provided'.

2.3. Societal Challenge 4 "Smart, Green and Integrated Transport"

2.3.1. Relevance and Coherence of the Intervention

Motivation for applying

One type of motivation for future applicants is related to technology and innovation considerations. The two main motivational drivers are 'Addressing specific scientific or technical questions, problems, and issues' (84% to a very large and very large extent) and 'Development of new processes, products and services' (73%). The factors that matter the least were 'Development of non-technological innovations' (26%) and 'Accessing funding for 'seed' research' (43%). Nevertheless, they remain tangible motivational drivers.

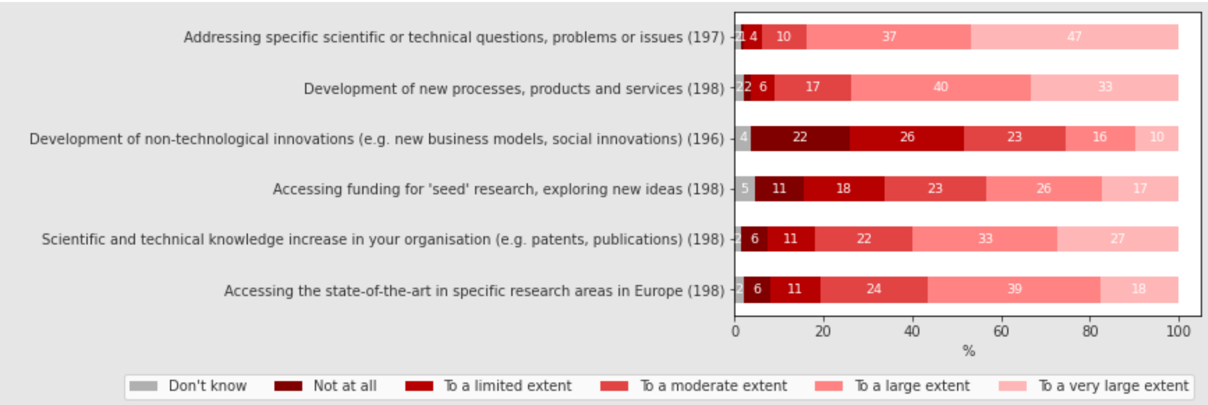


Figure 104 Q7: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 3 "Secure, clean and efficient energy"? Technology and innovation.

Climate and environment are another set of motivational drivers for applicants. The two main motivational factors are 'Contribution to development that avoids GHG emissions' (65%) and 'Addressing grand societal challenges related to the climate' (61%). The factors that matter the least were 'Reduction of the environmental impacts of the organisation' (32%) and 'Increasing resource efficiency of processes in your area' (55%). Nevertheless, they remain tangible motivational drivers.

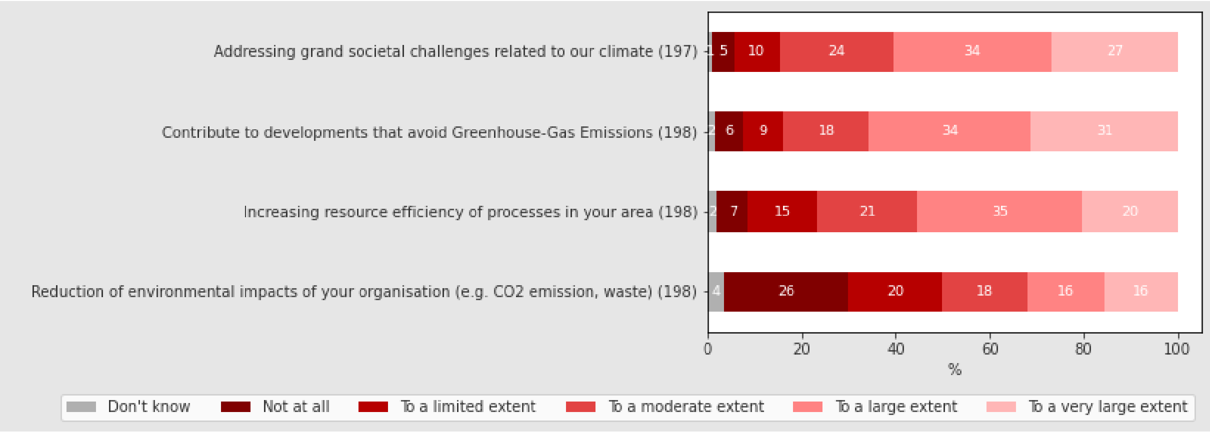


Figure 105 Q8: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 3 “Secure, clean and efficient energy”? Climate and environment-related.

Business development and competitiveness have been identified as key motivations for applicants. The biggest share of applicants was driven by a motivation to increase the visibility of the organisation (68% to a large and very large extent). This driver is followed by the 'Increase of productivity and competitiveness of the organisation (55%) and 'Diversification of the organisation activities' (37%).

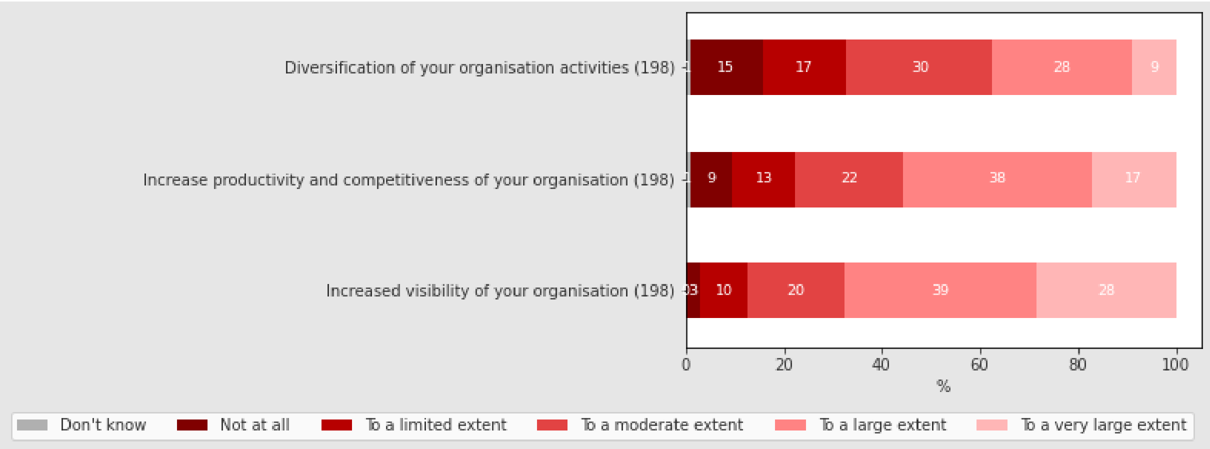


Figure 106 Q9: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 3 “Secure, clean and efficient energy”? Business development and competitiveness.

Collaboration is a major driver for participation in H2020 projects. Organisations were mainly willing to collaborate with other types of organisations (77% agree to a large and very large extent). Supposedly, this is an implicit acknowledgement of the value of the ecosystem as a whole. Sharing both costs and risks of a project is less of a driver with 36% of the respondents indicating it matters to a large and very large extent to them. 'Development of non-EU collaborations' is the weakest of the three collaboration-related drivers (31% to a large and very large extent).

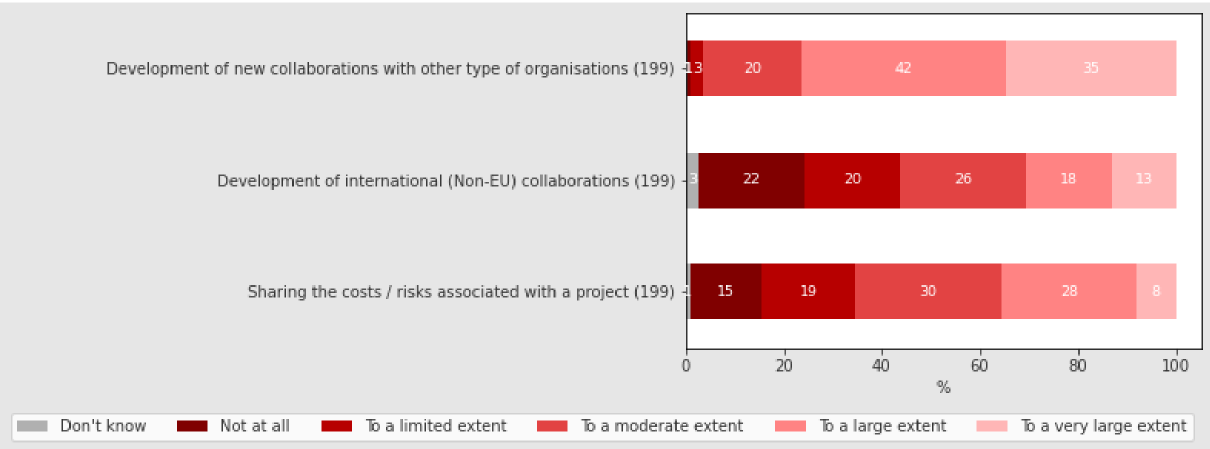


Figure 107 Q10: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 3 “Secure, clean and efficient energy”? Collaboration.

Needs and challenges

Between 32% and 73% of the respondents consider that their different needs and challenges have been addressed by the project to a large and very large extent. The challenge and needs which have been addressed to the highest extent are 'making transport more sustainable and respecting the environment' (73%), followed by 'increase the resource efficiency of the transport system' (69%) and 'decreasing emissions and other negative side effects of transport' (68%). The challenges and needs which have been addressed to the lowest extent are 'decreasing traffic congestion' (32%), 'making transport and transport systems seamless' (34%) and 'performing socio-economic research and forward-looking activities for policy making' (34%).

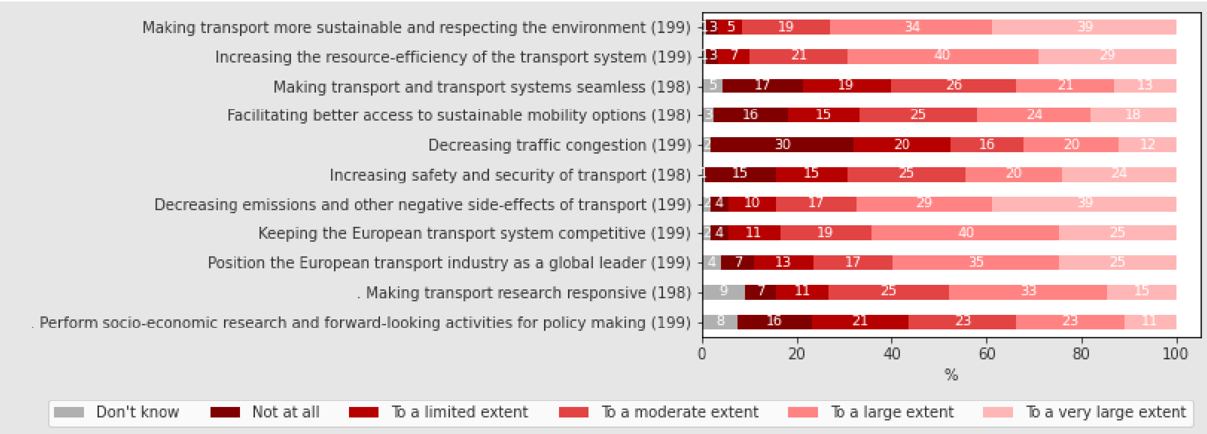


Figure 108 Q11: To what extent does your project address the following needs and challenges?

Collaboration

As pointed out previously, collaboration is a main motivational driver for H2020 participants. While the previous question was referring mainly to collaboration within the consortium, the one below targets collaboration with organisations outside the consortium. The intensity of collaboration was the highest with regards to research organisations (51% collaborated or co-led) followed by High Education Institutions (HEI) (44%). The lowest level of collaboration intensity was identified with regard to Research Funding Organisations (7%) and NGOs (13%).

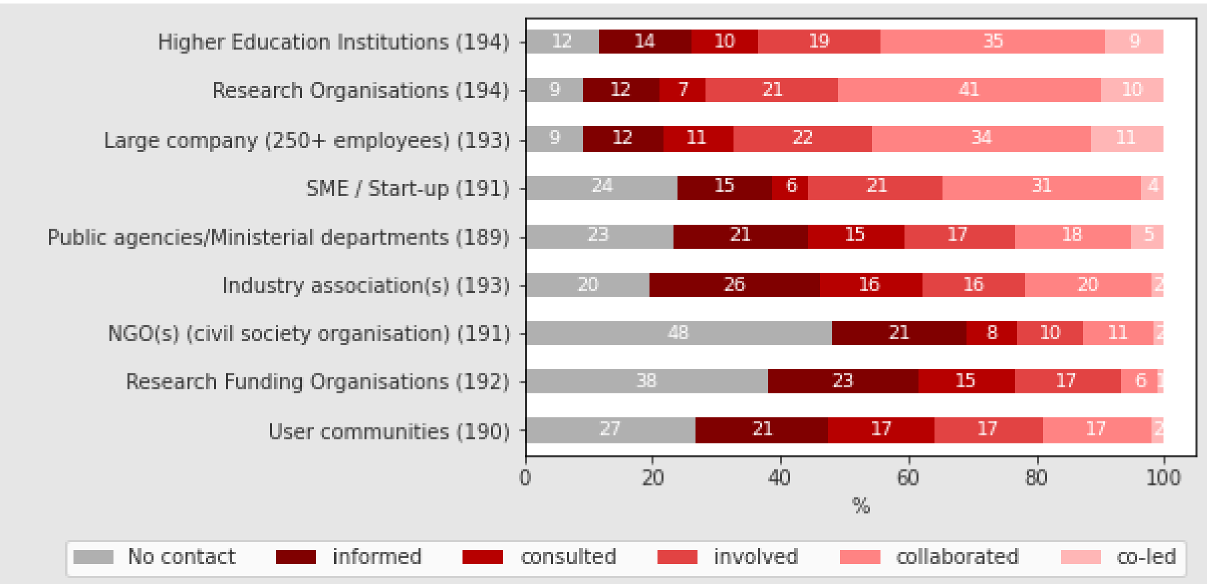


Figure 109 Q12: How intense was your collaboration with the following stakeholder groups outside the project consortium in the context of your project?

Some 67% of the respondents believed that all relevant stakeholder groups were addressed through the project activities. By responding ‘Partially’ the remaining 33% of the respondents believed that improvements were possible. Some of the recommendations for improvements are summarised after the table.

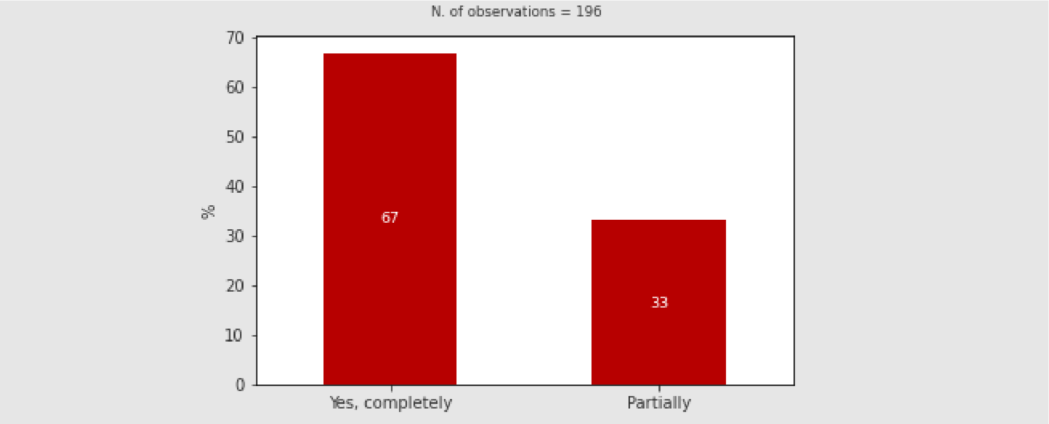


Figure 110 Q13: In your opinion, were all relevant stakeholder groups sufficiently addressed through the project activities?

Q14 Considerations with regards to stakeholder involvement:

- Well-designed projects reported to have sufficiently included all relevant stakeholders. For example, stakeholder involvement in smaller R&T projects with a limited duration and specific objectives proved to be successful in this. Some respondents mentioned the underlying co-production approach as a successful driving rationale.
- In regard to benefits beyond facilitated stakeholder involvement, respondents mention the advantages of clustering initiatives. In some cases, linking projects to achieve synergies via so-called implementation agreements proved successful.
- Stakeholder involvement in some cases benefited from national predecessor projects or complementary projects.
- Involving local entities turned out difficult in some cases due to legal obstacles in the implementation process.
- Many respondents point towards a lack of sufficient time and resources to involve all relevant stakeholders. Notably, the involvement of some stakeholders is more time-consuming than that of others, resulting in an imbalance.
- In some cases, data protection proved to be an obstacle. Commercially sensitive issues and contractual obligations with third parties restricted the exchange of information and hindered stakeholder collaboration.
- Respondents pointed towards the success of establishing an external advisory group formed from external stakeholders. This took place in addition to engagement activities with the stakeholders directly involved in the project.
- In some projects, respondents note that stakeholder involvement should take place early in the project development to influence the strategic orientation of the project.
- Specific ways of involving stakeholders that proved successful were for example surveys to users, consultation of researchers, conferences, webinars or the dissemination of results and findings. Additionally, the involvement of stakeholders as both partners and part of a project advisory board proved beneficial in some projects.
- Both the Russian attack on Ukraine and the global Covid 19 pandemic impacted certain projects and the possibility of including all relevant stakeholders.

- Some respondents point towards a lack of interest on the stakeholders' side. In other cases, stakeholders were highly interested in the project activities but less prone to contribute.

- Others lament their difficulty to involve specific stakeholders. Frequently mentioned is the failure to consult consumers e.g., the public transport passenger.

In addition, it should be pointed out that 27% of these respondents indicated that they have collaborated with non-European partners within the project.

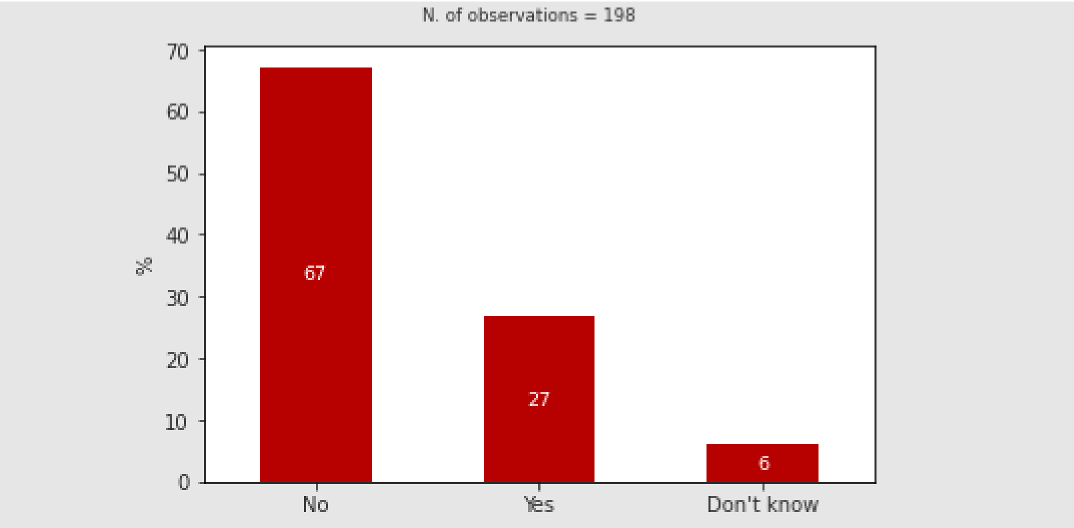


Figure 111 Q15: Have you collaborated with non-European partners as project partners in your project?

Those who collaborated with non-European partners pointed to several major benefits of this collaboration. 'Development of know-how' is the biggest identified benefit (75% - to a large or very large extent) followed by 'Development of new, additional partnerships' (70%). 'Access to new markets' and 'Reduction of the environmental impact of the organisation' have been the two smallest benefits (31% and 34% respectively).

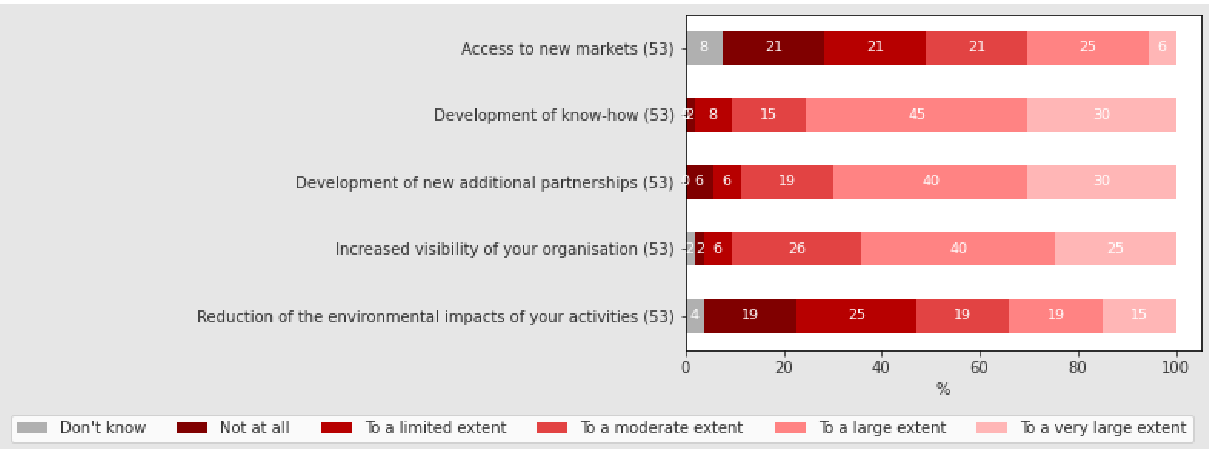


Figure 112 Q16: To what extent have you experienced the following benefits from the international cooperation in your project?

It has to be pointed out that some 46% of the respondents consider that cooperation with non-European partners contributes to a large or very large extent to improving the European position in the global competition. Some 23% think this advancement is to a moderate extent. Some 17% think it is either to a very limited extent or not at all while the remaining 14% either don't know or think it is too early to tell.

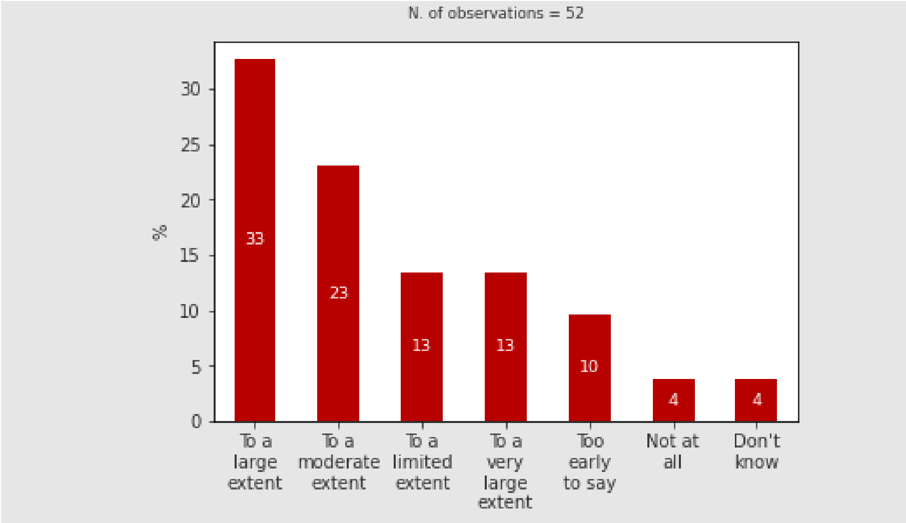


Figure 113 Q17: Has the cooperation with non-European partners in H2020 contributed to improving the European position in the global competition?

2.3.2. Effectiveness of the intervention

Results of the intervention

The answers to the survey revealed a high level of alignment between the objectives of the projects and their results. Some 87% of the respondents considered that these are fully aligned or aligned to a large extent. For 1% of the respondents, they are aligned to a limited extent.

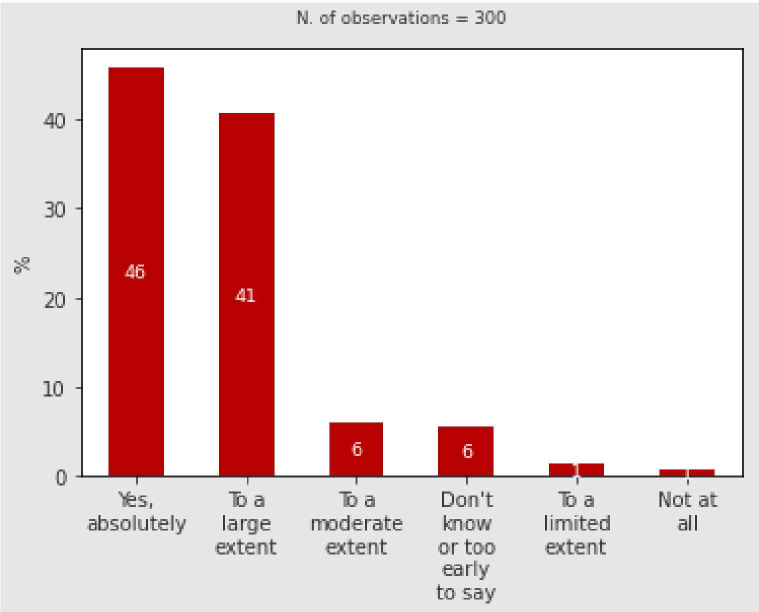


Figure 114 Q6: Are the results of your project in line with its objectives?

Between 26% and 66% of the respondents assess that the project contributed to a large or very large extent to the improvement of different aspects of expertise. 'Contribution to knowledge and capacity building' and 'Contribution to scientific and technological development' stand out as the aspects of expertise which have been improved to a large or very large extent (66% and 61%). 'Contribution to market and business development' and 'Contribution to policy making and standard setting measures' are the expertise components which have been improved to the lowest extent as only 25% and 31% of the respondents respectively consider that it has been improved to a large or very large extent.

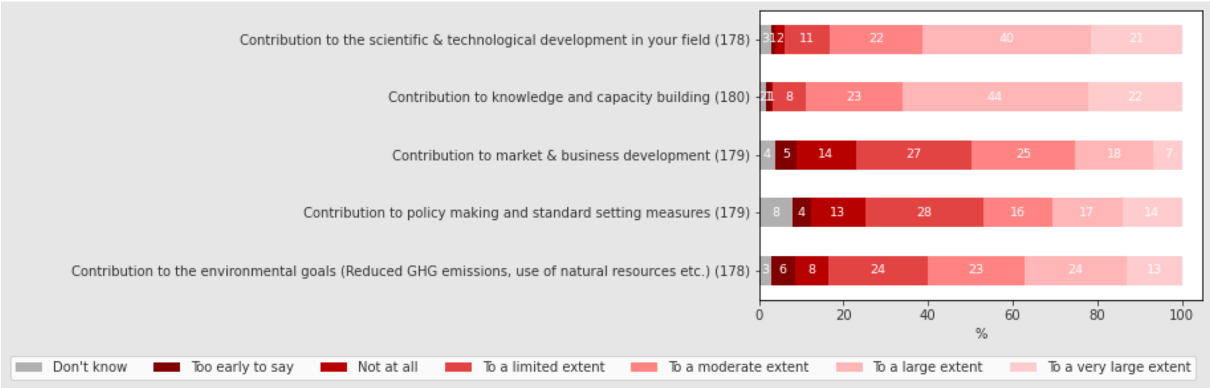


Figure 115 Q29: How successful was your project in terms of contributing to the following dimensions in your area of expertise:

Scientific results

Between 52% and 83% of the respondents assess that different scientific results have been fully achieved or achieved to a large extent. ‘Better understanding of the subject’ stands out as the scientific result which has been achieved to the highest extent (83%). It is followed by 'Better access to state-of-the-art research' (62%) and ‘Publications in peer-reviewed journals’ (53%). There is no anticipated scientific result which stands out with a low extent of achievement, the lowest being 'researchers trained' 'with 52%.

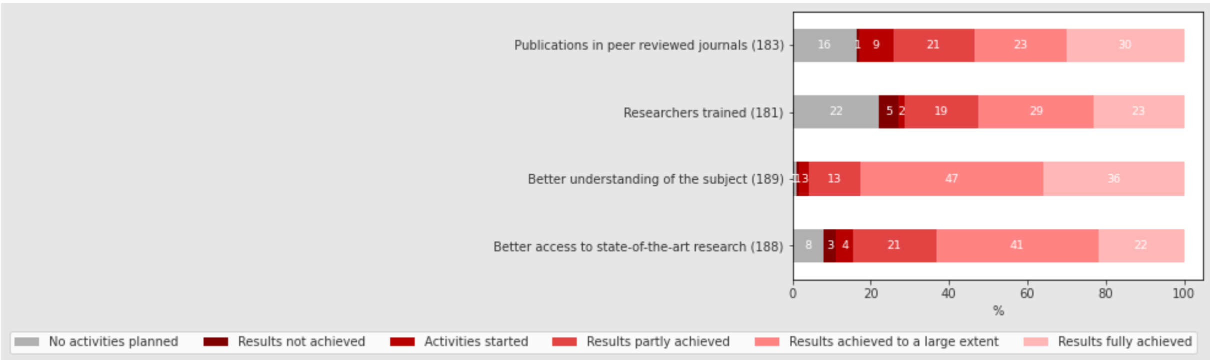


Figure 116 Q18: In terms of scientific outputs, what are the (anticipated) results of your project?

Technology and Innovation

Between 24% and 70% of the respondents assess that the technological development results have been fully achieved or achieved to a large extent.

'New research tools, models, simulations' and 'Expansion of basic knowledge for technological development' stand out as the technological development results which have been achieved to the highest extent (70% and 66%).

'Cost reduction of technology' and 'Development and improvement of production processes' (both 24%) are the anticipated technological development result which stand out with a low extent of achievement (full or to a large extent).

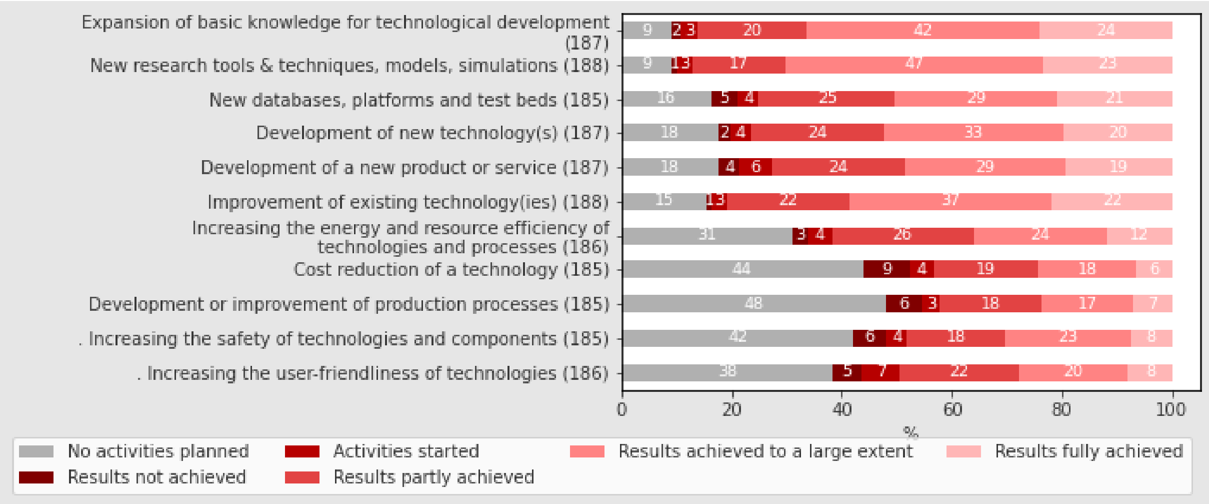


Figure 117 Q19: In terms of technological development outputs, what are the (anticipated) results of your project?

In terms of the contribution of the project to H2020 desired outcomes in Technology and Innovation, the respondents identified 'New generation of innovative and environmentally friendly air, waterborne and land transport means' and 'Solutions across technology fields and sectors' as the biggest achievements (44% and 42% respectively think that their projects contributed to these outcomes to a very large or large extent). On the other side of the spectrum, the outcomes achieved to the least extent are 'new European information and payment systems' (9%) and 'efficient interfaces between long-distance and urban mobility networks' (17%).

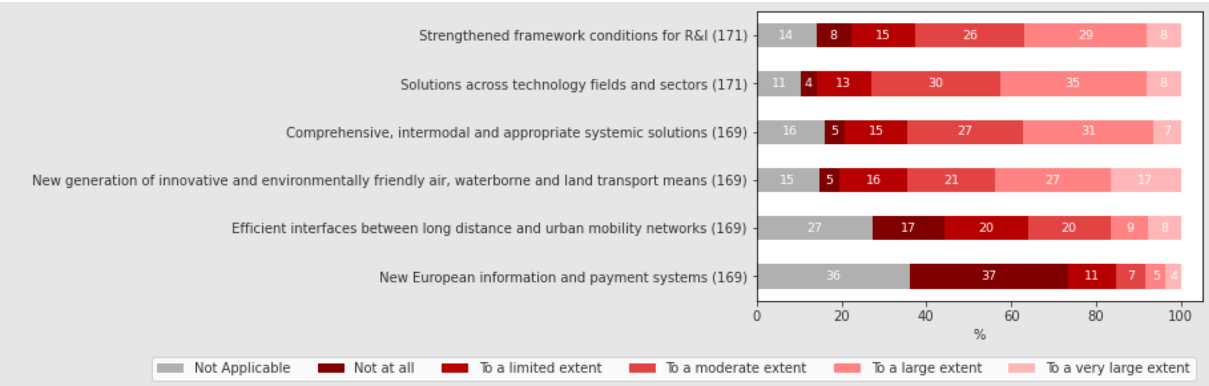


Figure 118 Q30: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Technology and Innovation.

Between 14% and 58% of the respondents assess that the system development results have been fully achieved or achieved to a large extent.

'Demonstration or pilot feasibility of technological solutions' and 'Integration of technology' are the system development results which have been achieved to the highest extent (58% and 51%).

'Developing innovations in marketing and sales' (14%), 'Developing of social innovations' (17%) and 'Development of organisational innovations' (21%), are the anticipated market development results which stand out with a low extent of achievement (full or to a large extent).

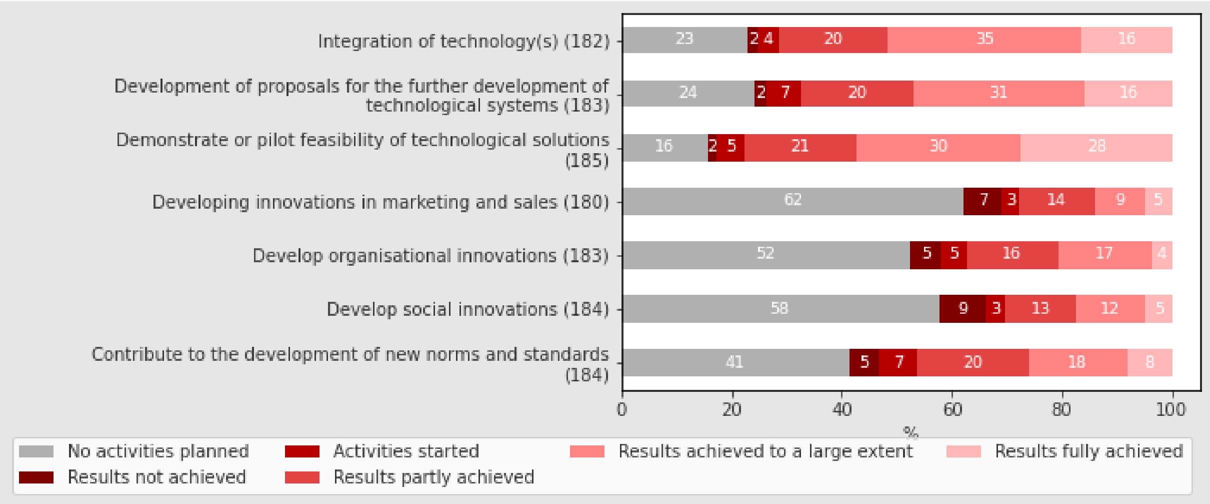


Figure 130. Q21: In terms of system development, what are the (anticipated) results of your project?

With regards to Technology readiness 14% of the respondents consider that the TRL concept cannot be applied to their project.

Initially, half of the respondents considered their overall TRL level as 3 (25%) and 2 (25%). This dropped significantly at the end of the projects (10% and 2% respectively). The second biggest progress in the initial TRL level to the current TRL level can be seen for TRL 4, which shows a change from 15% to 30%. A similarly, steep increase accounts for TRL 7 now considered by 14% of respondents compared to 2 % initially. While it is difficult to gauge the progress within the same project, we observe that the overall level of the TRL has increased across the board.

An additional analysis was done regarding the distribution of types of actions. This showed that for the highest percentage of CSA projects, the TRL was not applicable. IA projects were found to be mainly in a high TRL stage. For RIA projects most projects were in low TRL stages.

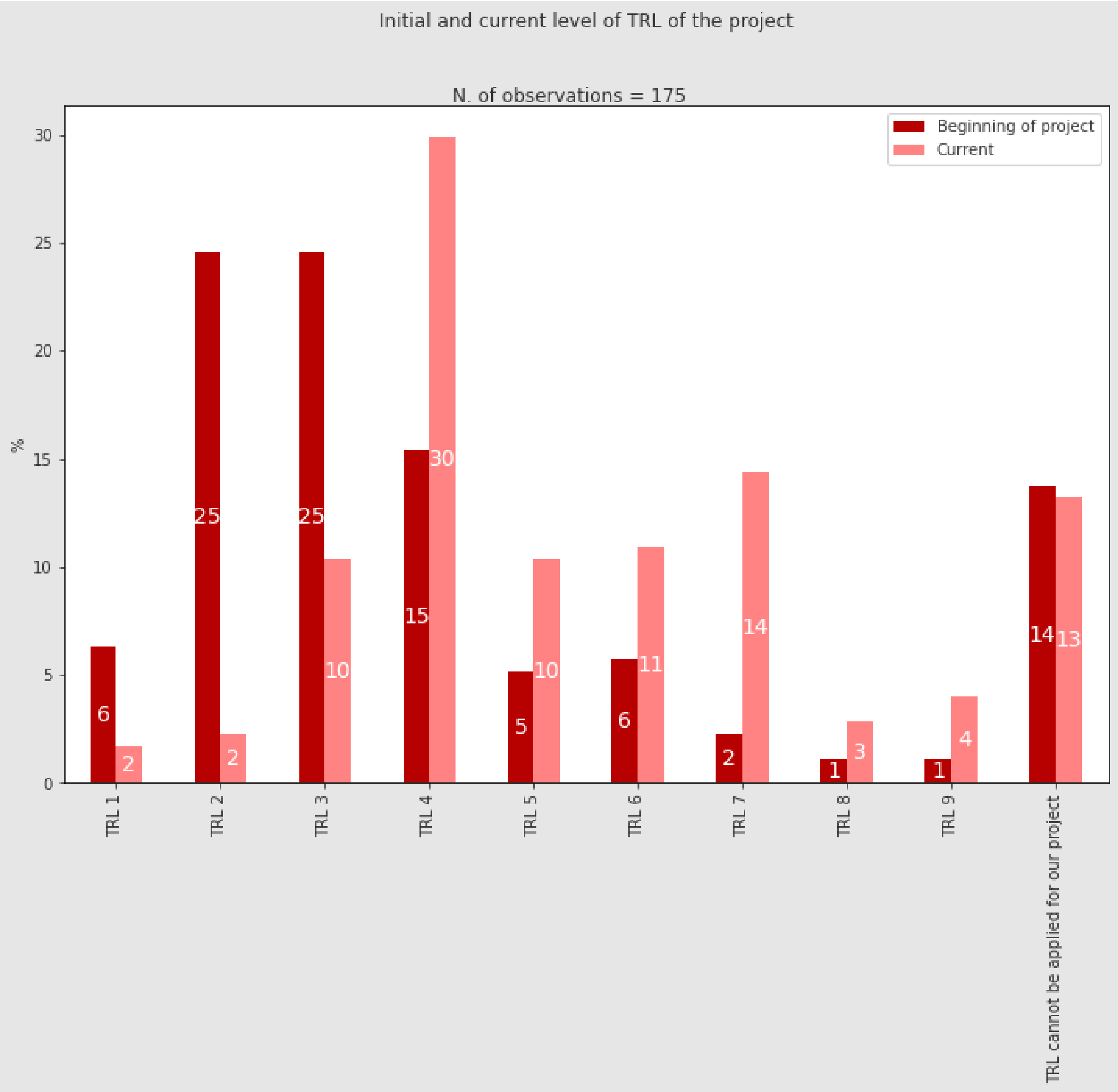


Figure 131. Q22: What was the overall level of Technology-Readiness at the beginning of the project (TRL)? And Q23: What is the current overall level of Technological-Readiness of your project's technological development?

In addition, it should be noted that TRL 4 is the most common target TRL level with 29%. Followed by TRL 6 (13%), TRL 7 (13%) and TRL 5 (11%). Again, a significant share of respondents indicated that the TRL concept cannot be applied to their project (14%).

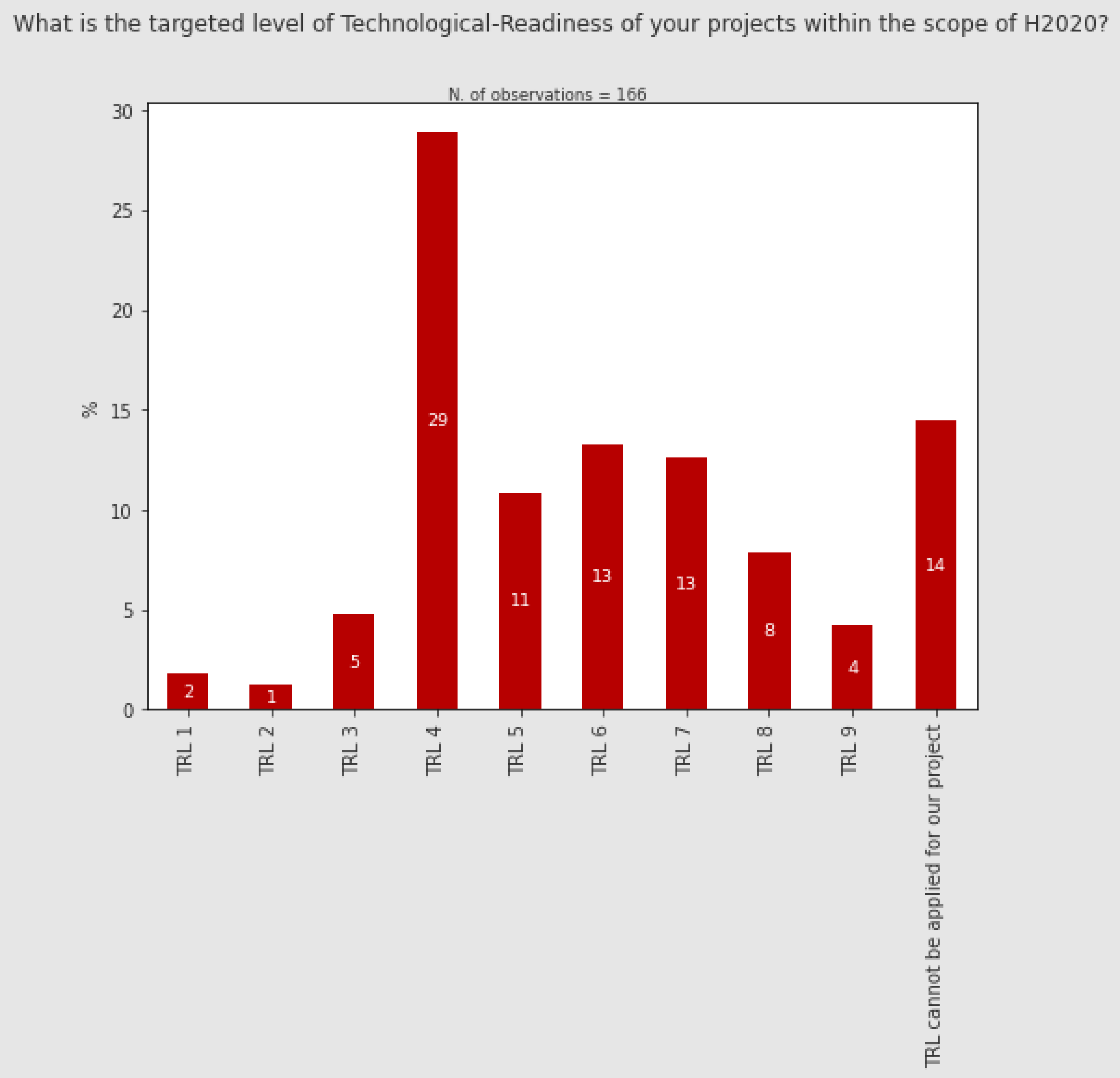


Figure 119 Q24: What is the targeted level of Technological-Readiness of your projects within the scope of H2020?

Knowledge and Capacity

Between 22% and 50% of the respondents assess that the project influenced their organisation to a large or very large extent with regard to different organisational aspects.

'Intensified collaboration on R&D with new organisations' and 'Increased focus on interdisciplinary research' are the two aspects for which the project has influenced the organisations to a large and very large extent (50% and 49%).

'Increased focus on risk-oriented research', is the aspect of the organisation which stands out as only 22% of the respondents thought it had been influenced to a large or very large extent.

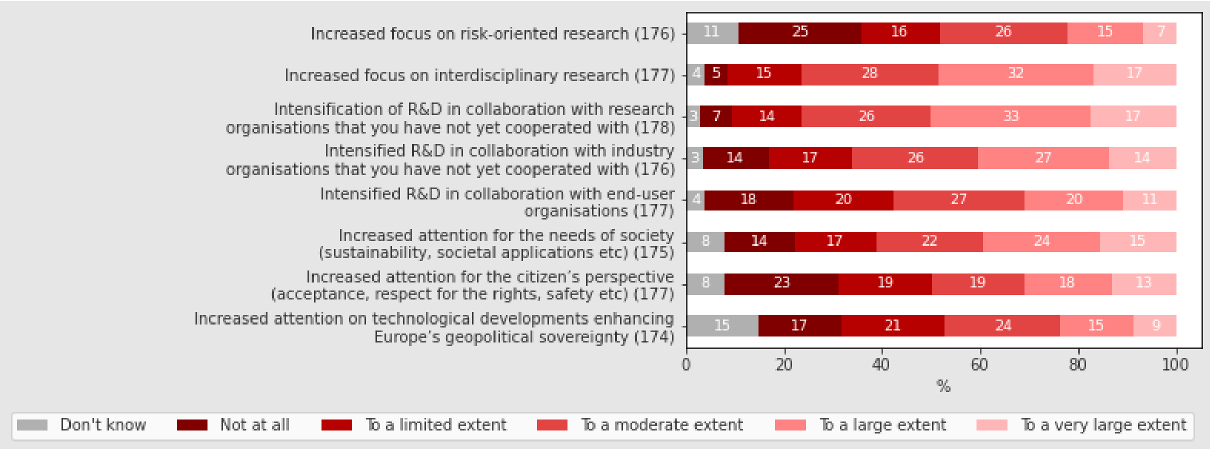


Figure 120 Q26: To what extent did your project influence the following aspects of your organisation?

With regard to the contribution of the project in terms of enabling several desired outcomes. 'Strengthening R&I capacities in your area' and 'EU excellence in science and innovation' stand out as the two outcomes achieved to the largest extent (55% and 51% respectively). The two desired outcomes which have been achieved to the lowest extent are 'New European multimodal transport management systems' (36%) and 'More service-oriented transport system' (39%).

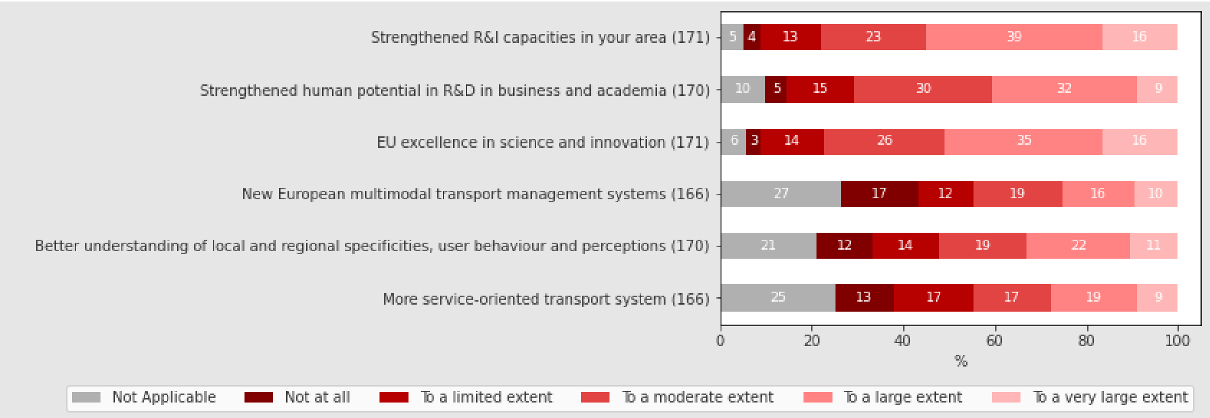


Figure 121 Q31: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Knowledge & Capacity

Coordination and collaboration

Between 16% and 56% of the respondents considered that their projects contributed to the different desired outcomes of Horizon 2020.

The first four outcomes have been achieved almost to an identical extent at around 51-56% of the respondents considering the contribution to be to a large or very large extent. 'Stronger involvement of civil society in R&I' stands out as the outcome to which projects have contributed the least.

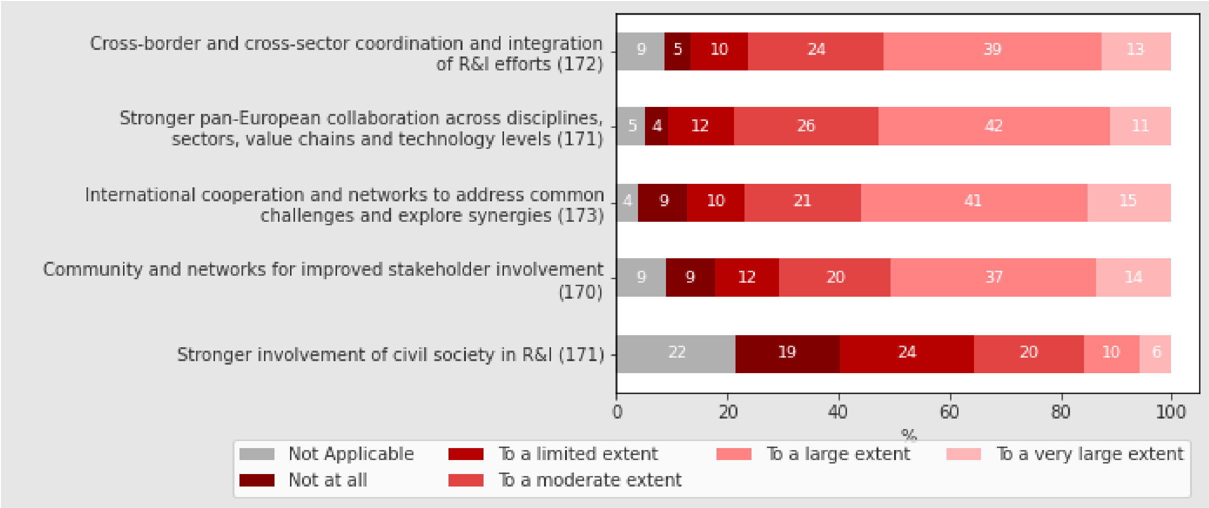


Figure 122 Q32: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Coordination & Collaboration.

Markets and business

Between 2% and 37% of the respondents assess that the market development results have been fully achieved or achieved to a large extent.

'Development of marketable products or services' and 'Market launch of new products/services' are the market development result which has been achieved to the highest extent (37% and 27% respectively).

'Creation of a start-up' and 'Creation of a spin-off, are the anticipated market development results which stand out with a low extent of achievement (full or to a large extent) (2% and 3% respectively).

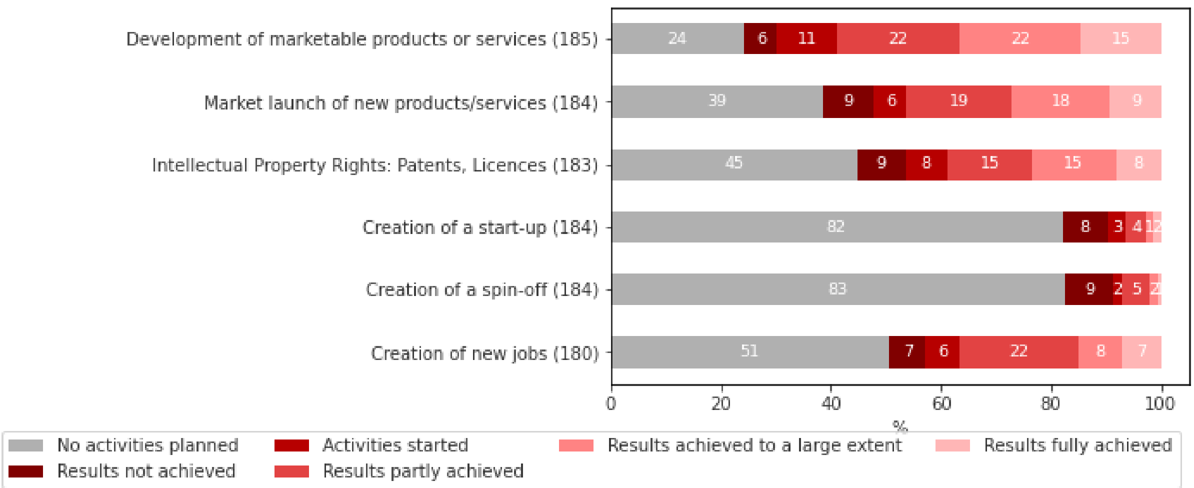


Figure 123 Q20: In terms of market development, what are the (anticipated) results of your project?

Some 38% of the respondents think that the project has contributed to a large or very large extent to the improvement of the time-to-market of technological solutions. Inversely, 21% consider that this has happened to a limited extent (16%) or not at all (5%). Some 19% of the respondents are not aware of the effect of the project on the 'time-to-market' of new solutions.

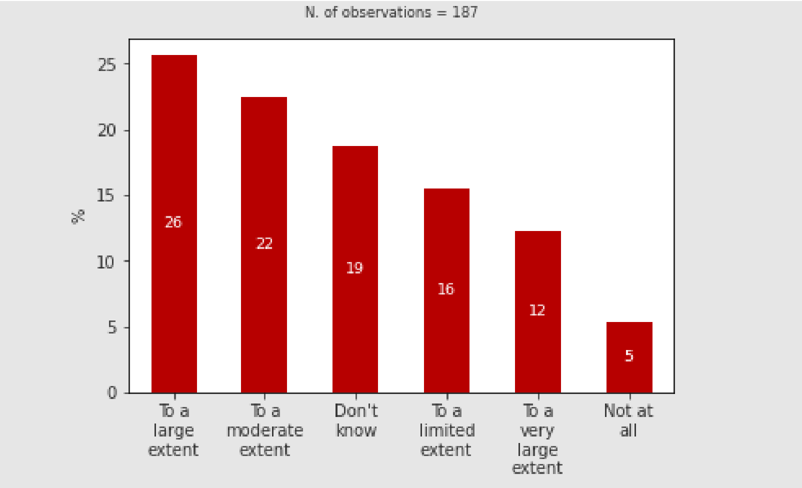


Figure 124 Q25: Has the project contributed to improve the "time-to-market" of new solutions?

No more than 6% of the respondents consider that the project led to a 20% or more increase in turnover, employment or profit. Between 3% and 6% of the respondents think that there has been an incremental increase between 11% and 20% for these three aspects. Between 25% and 32% of the respondents think that there has been an incremental increase between 1% and 10% for these three aspects. Between 56% and 70% of the respondents either don't know if there has been an increase in these three aspects or think that there has been no change.

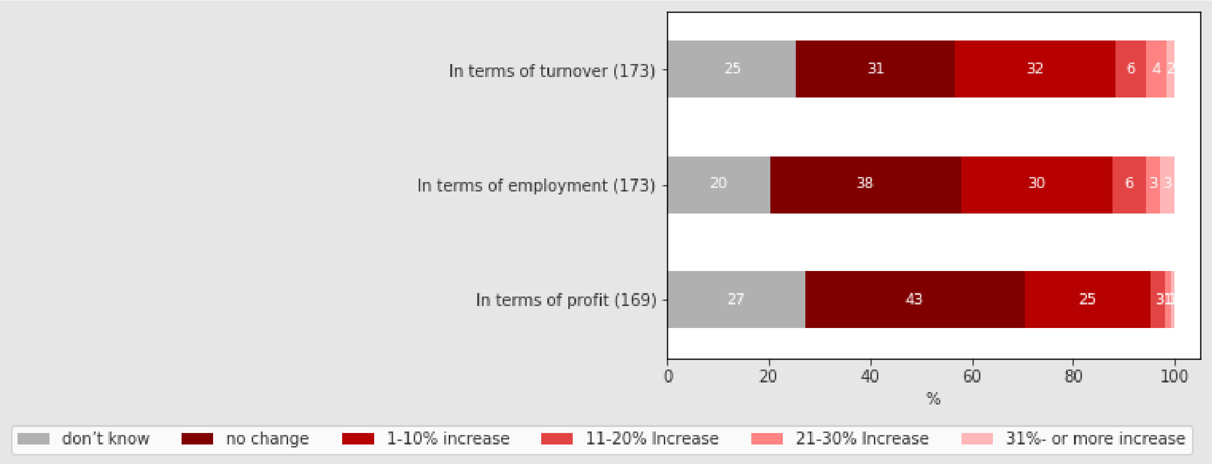


Figure 125 Q27: To what extent has your participation in H2020 led to the following economic benefits (or is it expected to do so after project completion) in your operational unit? Please provide best estimates.

Between 25% and 39% of the respondents assess that the project influenced their competitiveness nationally (39%), in Europe (39%) or internationally (25%) to a large or very large extent. Around 28-32% think that the increase has been to a moderate extent. Between 29% and 44% of the respondents either 'don't know or think it is too early to say' or think that the project influenced their competitiveness nationally, in Europe or internationally not at all or to a very limited extent.

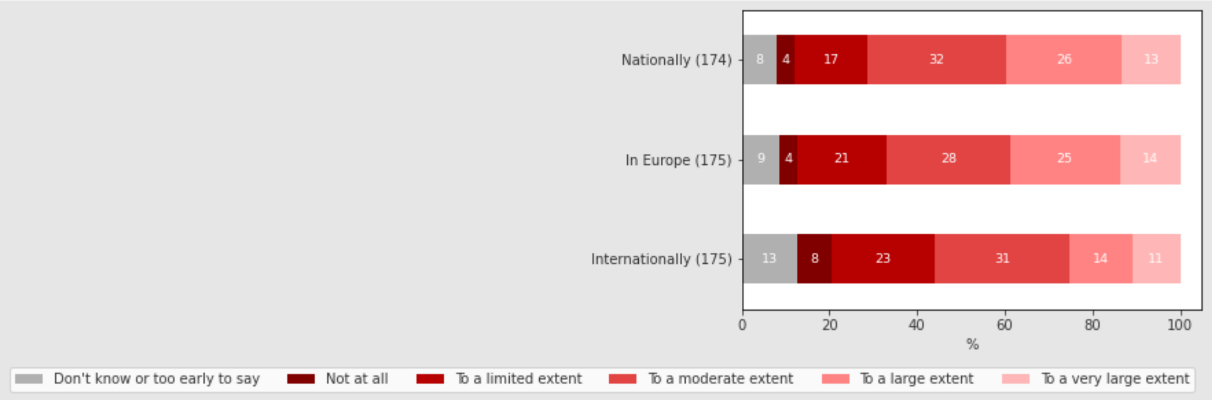


Figure 126 Q28: Do you consider that your project contributed to the increase of the overall competitiveness of your operational unit?

Between 14% and 42% of the respondents think their project contributed to a large or very large extent to the different desired outcomes. The share is the highest for the outcome ‘More competitive industry’ (42%) followed by ‘Reduced time to market’ (27%) The share is the lowest for the outcome ‘Higher consumer awareness and acceptance’. It has to be noted that a significant portion of the respondents think the contribution has been moderate.

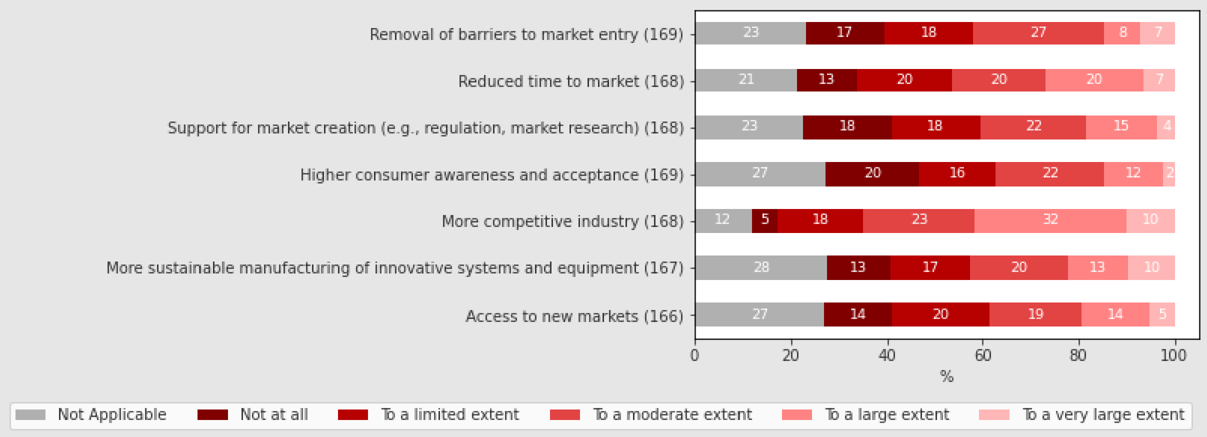


Figure 127 Q33: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Market & Business.

Policies and standards

Between 26% and 28% think the projects contributed to the desired outcomes in terms of policies and standards to a large or very large extent. 'New transport standards' comes first (28%), followed by 'More robust and transparent policy-making' (27%) and more innovation-conducive regulatory frameworks. Inversely, between 48 % and 54 % think the projects contributed not at all or to a limited extent to the outcomes or the question is not applicable.

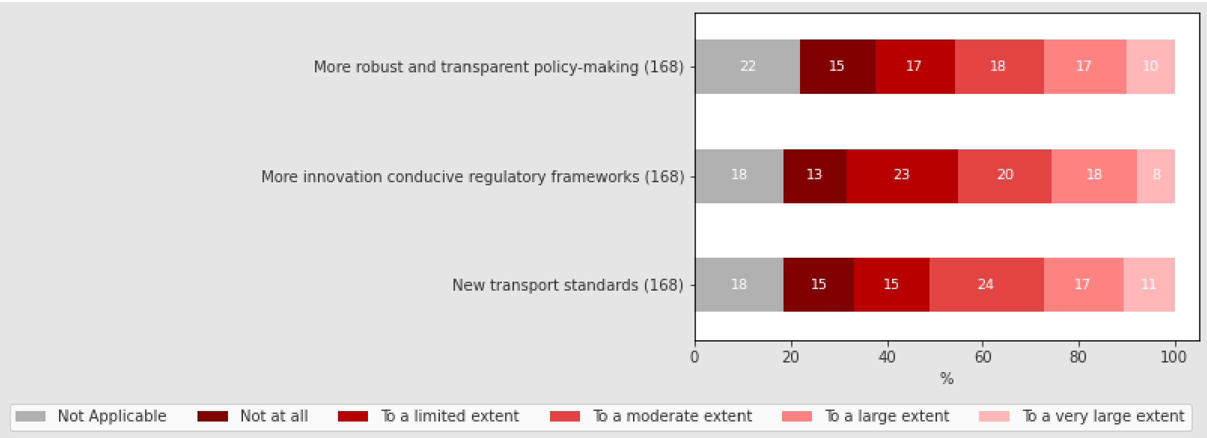


Figure 128 Q34: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Policies & Standards.

Barriers and enabling factors

Between 11% and 29% of the respondents consider that different types of barriers impede the successful uptake of their projects to a large or very large extent. The two barriers which stand out are ‘Limited financial resources for the implementation of project results’ (29%) and ‘Impact of COVID19 pandemic’ (20%). If respondents who chose that the influence is moderate are added to the figures, then ‘Lack of internal organisational support for implementation’ and ‘High economic risk’ are also tangible with 41% and 44% respectively. Overall, all the mentioned barriers are valid.

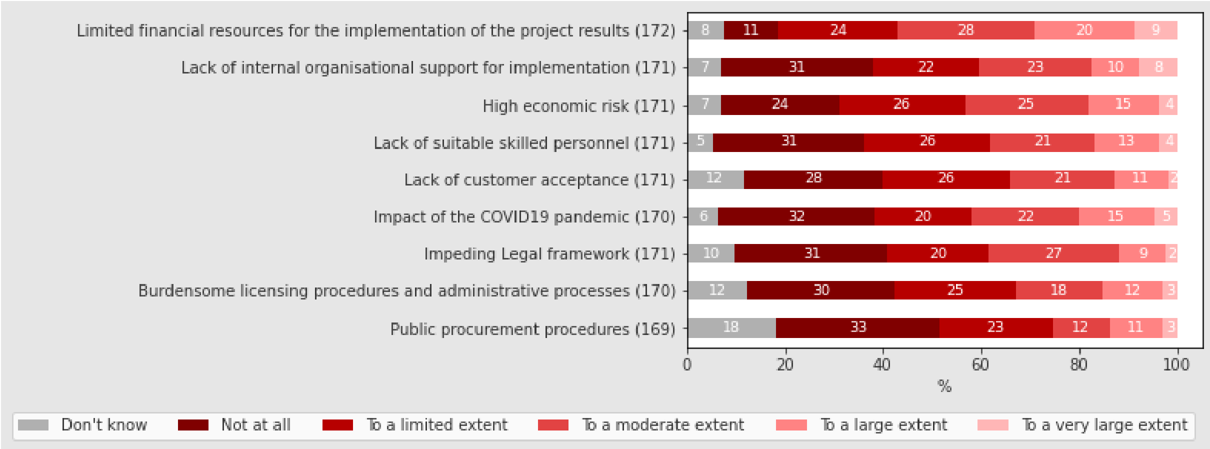


Figure 129 Q35: Barriers and enabling factors: Do you see barriers that impede a successful uptake of results of your project?

Dissemination, exploitation and communication

A significant majority of respondents think that dissemination, exploitation, and communication activities have been both useful (71% to a large and very large extent) and sufficient (59%). Less than 8% don't know or consider that they have been neither useful nor sufficient.

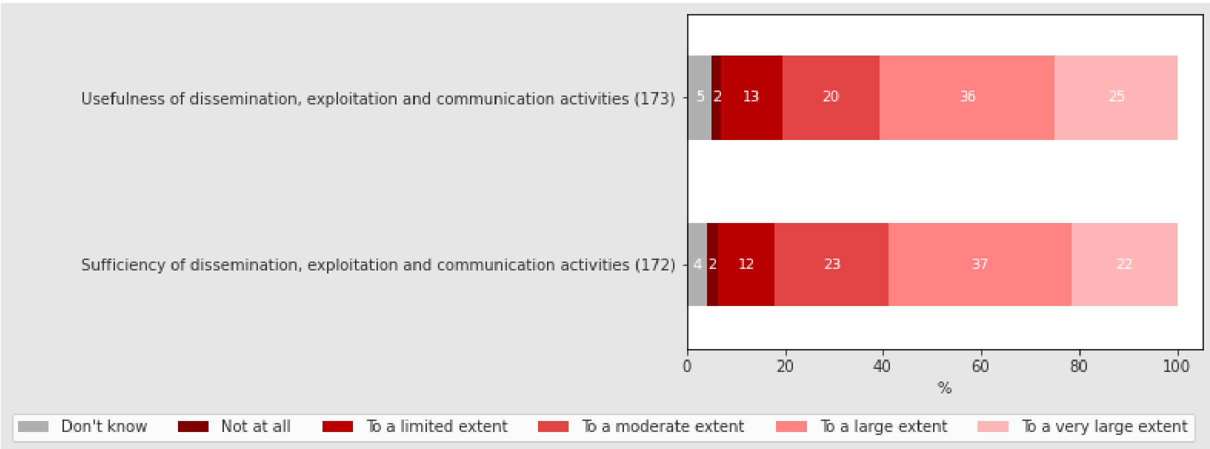


Figure 130 Q36: To which extent have the dissemination, exploitation and communication activities been useful and sufficient in the uptake of your project results?

2.3.3. EU added value

Between 36% and 79% of the respondent agree to a large and very large extent that H2020 provided an EU-added value in several aspects. The highest agreement is on the diversity of partners' profiles (79%), followed by multi-cultural aspects of the consortia and funding opportunities for specific topics (both 77%). The lowest value added is on 'technical support provided' (33%), followed by flexibility given to respond to changing socio-economic needs (36%).

Figure 131 Q50: To what extent do you see added value from funding Horizon 2020 projects compared to funding on a national or regional level?

Some 62% of the respondents answered that the project would not have been implemented; 72% - the scope would have been reduced; 47% that it would have been implemented with other partners; 20% that it would have been funded on a national or regional level; 39% that its timeline would have been extended; and 45% that it would have been delayed.

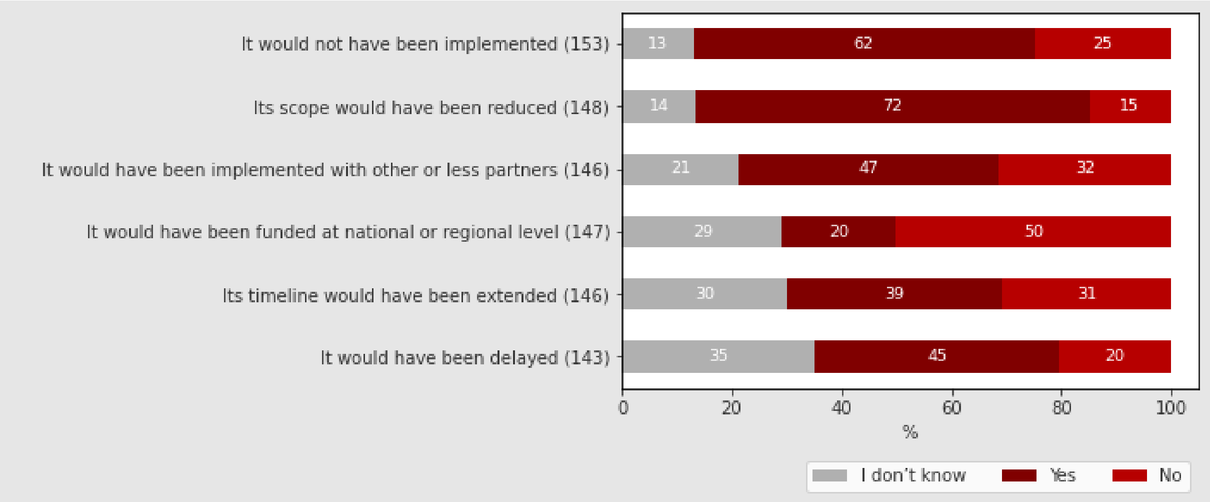


Figure 132 Q51: Without support from H2020, what would have happened to your project?

2.3.4. Summary

Relevance and coherence

In terms of technology and innovation, the two main **motivational drivers** for respondents are 'addressing specific scientific or technical questions, problems and issues' and 'development of new processes, products and services'. 'Accessing funding for 'seed' research' did not appear to be of the same importance. As far as climate and environment are concerned, 'Contribution to development that avoids GHG emissions' and 'Addressing grand societal challenges related to the climate' were the biggest motivators for participation in the Framework Programmes. From a business and competitiveness point of view, 'improving the visibility of the organisation' exceeded other motivational factors such as 'increasing the productivity and competitiveness of the organisation' and 'diversification of the organisational activities'. Collaboration is a strong driver for participation in FPs, especially the 'development of new collaborations with other types of organisations' and much less so 'sharing the risks of a project' and 'developing collaborations with non-EU organisations'.

The needs and challenges of projects have been addressed to varying extents. *'Making transport more sustainable and respecting the environment'* has been addressed to the highest extent. The challenges and needs which have been addressed to the lowest extent are *'decreasing traffic congestion', 'making transport and transport systems seamless'* and *'performing socio-economic research and forward-looking activities for policy making'.*

Collaboration is key for H2020 projects, and its intensity was the highest with *Research Organisations* and *Higher Education Institutions* which exceeded by far collaboration with other types of stakeholders. On the other end of the spectrum, collaboration was lowest with *NGOs* and *Research Funding Organisations*.

With regards to **involving stakeholders** in the work of the projects, 67% noted that all relevant stakeholders were addressed, while 40% thought this was done only partially. Identified reasons for this are diverse, ranging from the effects of Covid-19 or the Russian attack on Ukraine to lacking time and resources or disinterest on the stakeholder side. Additionally, respondents noted legal hurdles and data protection rules that hindered stakeholder collaboration. **Collaboration with non-EU partners** took place for less than a third of the respondents but those who collaborated saw benefits from it the main one being *the 'development of know-how'*. *'Access to new markets'* has not been identified as a major benefit. Respondents are split with regards to a positive contribution of cooperation with non-EU partners on the European position in the global competition: almost half consider this to be the case to a large and very large extent, while the remaining half is either in disagreement, does not know or considers it too early to tell.

Effectiveness

According to survey responses, there is a high level of alignment between project objectives and results. From a **knowledge** perspective, the project contributed to the largest extent to *'knowledge and capacity building'* and *'scientific and technological development'*. *'Contribution to market and business development'* has been the lowest. In terms of **scientific results**, respondents consider that the project contributed to the largest extent to *a 'better understanding of the subject'* and *'better access to state-of-the-art research'.*

With regards to **technology and innovation**, the share of respondents who consider results have been fully achieved or achieved to a large extent is lower than for knowledge- and science-related results. *'New research tools, models, simulations'* and *'Expansion of basic knowledge for technological development'* are the two technological development results which have been achieved to the highest extent. *'Cost reduction of technology'* and *'Development and improvement* of *production processes'* have been achieved to the lowest extent. In terms of technological development outputs, the respondents identified *'New generation of innovative and environmentally friendly air, waterborne and land transport means'* and *'Solutions across technology fields and sectors'* as the biggest achievements. **System development results** are considered as achieved fully or to a large extent by no more than 58% of the respondents. '*Demonstration of pilot feasibility of technological solutions'* and *'Integration of technology'* are the system development results which have been achieved to the highest extent. However, different types of innovations in marketing and sales,

and organizational and social innovations are on the low end.

The **technology readiness** for half of the projects was TRL2 and TRL3 at the start of the project. The overall TRL levels at the end of the projects do not allow comparison between TRL levels at the start and

the end of the same project. Nevertheless, it could be said that the reduced number of TRL2 and TRL3 projects and the steep increase in the number of TRL 7 and 4 and TRL7 projects means an overall gain in TRL level. The **TRL concept** has not been considered relevant by 14% of the respondents.

Organisational knowledge has been influenced to a large and very large extent for 22%-50% of the respondents, the largest focus being on *'intensified collaboration on R&D with new organisations'* and *'increased focus on interdisciplinary research'*. At the same time *'Increased focus on risk-oriented research'* has been influenced by only one-fifth of the respondents. Around half of the respondents validated the assumption that projects strengthened R&I capacities and EU excellence in science and innovation.

With regards to **coordination and collaboration**, four of the outcomes have been achieved to a large or very large extent by two-thirds of the respondents. These include cross-border and cross-sectoral integration; stronger pan-European collaboration across sectors; networks to address common challenges; and community and networks for improved stakeholder involvement.

Market and business have been identified as large or very large achievements by less than half the respondents. *'Development of marketable products or services'* and *'Market launch of new products and services'* are on the highest end while *'Creation of start-ups and spin-offs'* have been achieved to a large or very large extent by less than 5% of the respondents. Almost 40% think the time-to-market of technological solutions has been improved. The impact of the project on the microeconomic bottom line – turnover, employment, profit - of the project is very limited. A slightly bigger share of the respondents thinks the project improved their competitiveness, mostly in Europe and nationally and to a lesser extent – internationally. The relatively low level of perceived impact on market and business is also reflected in the perceived impact on different types of related outcomes. The most successful outcome *'More competitive industry'* has been achieved to a large and very large extent by only 42% of the respondents.

In terms of policies and standards, desired outcomes have been achieved to a large and very large extent by 26-28% of the respondents. Key policy outcomes such as *'New transport standards'* and *'More robust and transparent policy making'* have been achieved by slightly more than a quarter of the respondents.

Different barriers impede project uptake to a varying degree, limited financial resources being the biggest obstacle followed by an impeding legal framework. It is positive that even for these two barriers the share of respondents does not exceed 29%.

The huge majority of respondents think that **dissemination, exploitation and communication** activities have been both useful (71% to a large and very large extent) and sufficient (59%).

EU added value

Between 36 and 79% of the respondents think that H2020 provided an EU-added value in several aspects to a large and very large extent. This is particularly the case regarding the *'diversity of partner profiles'* followed by the *'multi-cultural aspects of the consortia'* and *'funding opportunities for specific topics'.* On the other end, 'Technical support provided' has been the lowest. An overwhelming majority of respondents answered that the project would have been implemented with a reduced scope without support from H2020.

2.4. Societal Challenge 5 "Climate action, environment, resource efficiency and raw materials"

2.4.1. Relevance and Coherence of the Intervention

Motivation for applying

One type of motivation for future applicants is related to technology and innovation considerations. The two main motivational drivers are 'Addressing specific scientific or technical questions, problems and issues' (85% to a very large and very large extent) and 'Development of new processes, products and services' (70%). The factors that matter the least were 'Accessing funding for seed research' (40%) and 'Development of non-technological innovations' (43%). Nevertheless, they remain tangible motivational drivers.

Figure 133 Q7: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 5 "Secure, clean and efficient energy"? -Technology and innovation.

Climate and environment are another set of motivational drivers for applicants. The two main motivational factors are 'Addressing grand societal challenges related to the climate' (75%) and 'Increasing resource efficiency of processes in your area' (63%). The factors that matter the least were 'Reduction of the environmental impacts of the organisation' (38%) and 'Contribute to developments that avoid Greenhouse-Gas Emissions (60%). Nevertheless, they remain tangible motivational drivers.

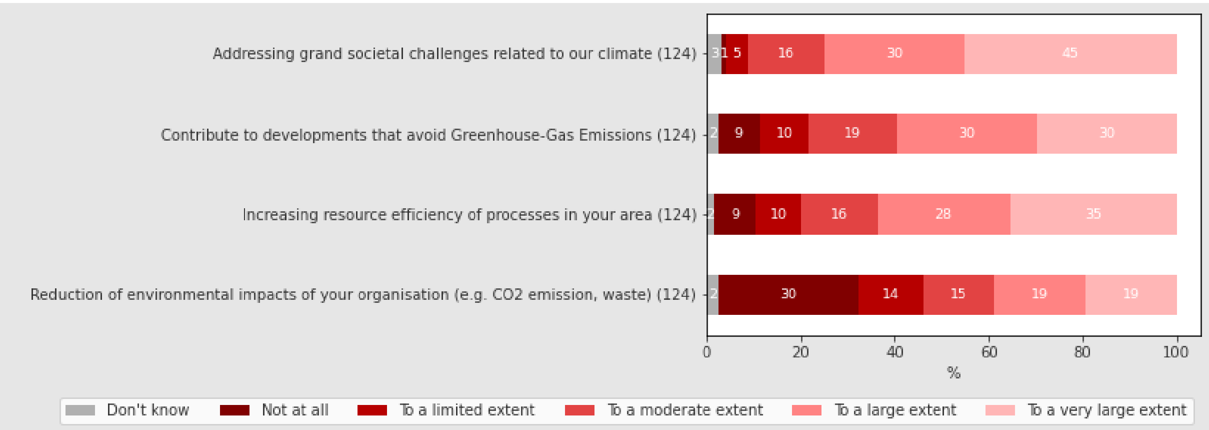


Figure 134 Q8: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 5 “Secure, clean and efficient energy”? -Climate and environment-related.

Business development and competitiveness have been identified as key motivations for applicants. The biggest share of applicants was driven by a motivation to increase the visibility of the organisation (64% to a large and very large extent). This driver is followed by the 'Increase of productivity and competitiveness of the organisation (57%) and 'Diversification of the organisation activities' (42%).

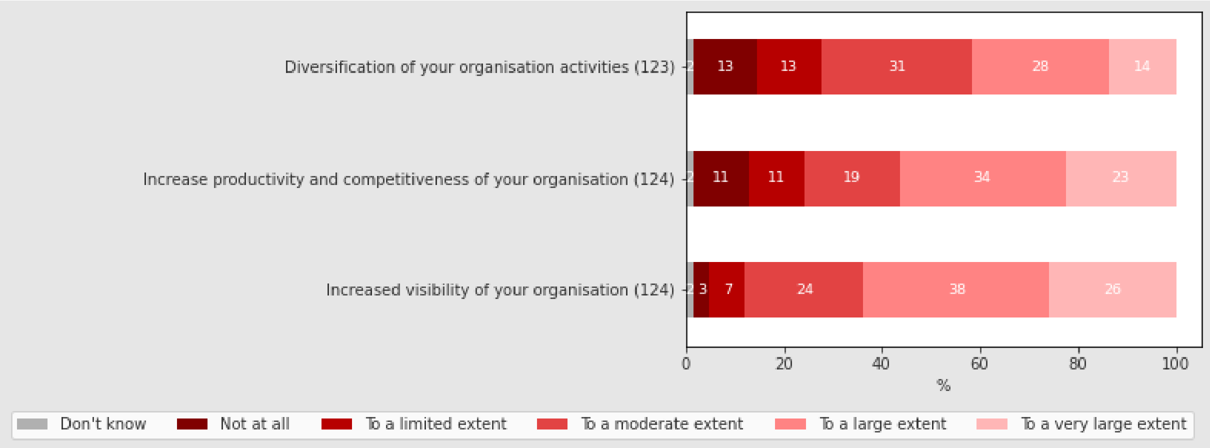


Figure 135 Q9: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 5 “Secure, clean and efficient energy”? -Business development and competitiveness

Collaboration is a major driver for participation in H2020 projects. Organisations were mainly willing to collaborate with other types of organisations (88% agree to a large and very large extent). Supposedly, this is an implicit acknowledgement of the value of the ecosystem as a whole. 'Sharing the costs/risk of a project’ is less of a driver with 39% of the respondents for which it matters to a large and very large extent. ‘Development of non-EU collaborations’ is the weakest of the three collaboration-related drivers (37% to a large and very large extent).

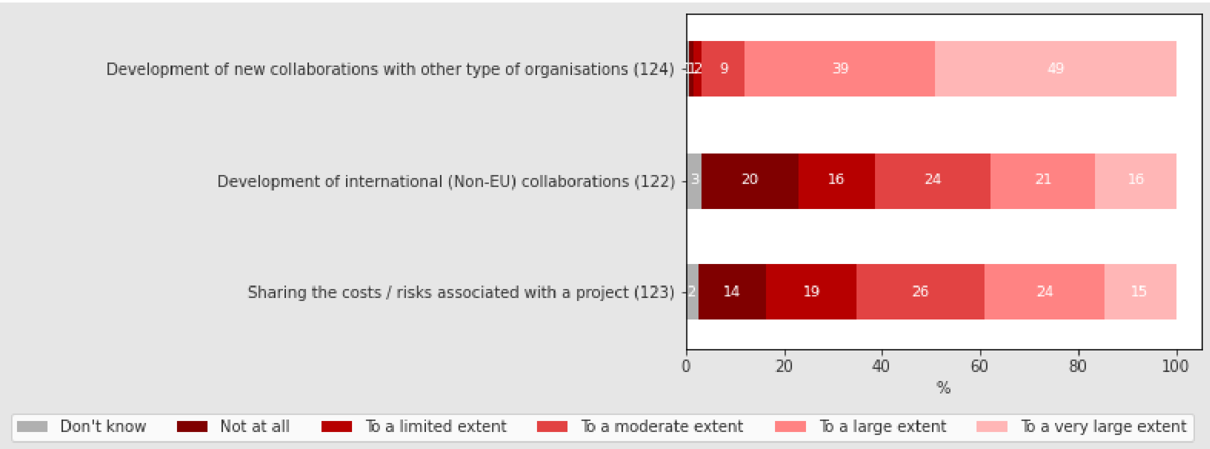


Figure 136 Q10: To what extent did the following factors encourage you to apply for H2020 funding under Societal Challenge 5 “Secure, clean and efficient energy”? -Collaboration.

Needs and challenges

Between 21% and 66% of the respondents consider that their different needs and challenges have been addressed by the project to a large and very large extent. The challenge and needs which have been addressed to the highest extent are 'Protection of the environment, sustainably managing natural resources, water, biodiversity and ecosystems' (66%), followed by 'Improved climate change mitigation and adaptation policies building on better evidence on key climate processes and a more accurate understanding of necessary societal and technological changes' (63%) and 'Eco-innovation enabling transition towards a green economy and society by generating environmental and economic benefits' (54%). The challenges and needs which have been addressed to the lowest extent are 'Protecting cultural heritage from climate change damage and maximising its opportunities for economic growth' (21%) and 'Developing comprehensive and sustained global environmental observation and information systems, including Earth Observation' (32%).

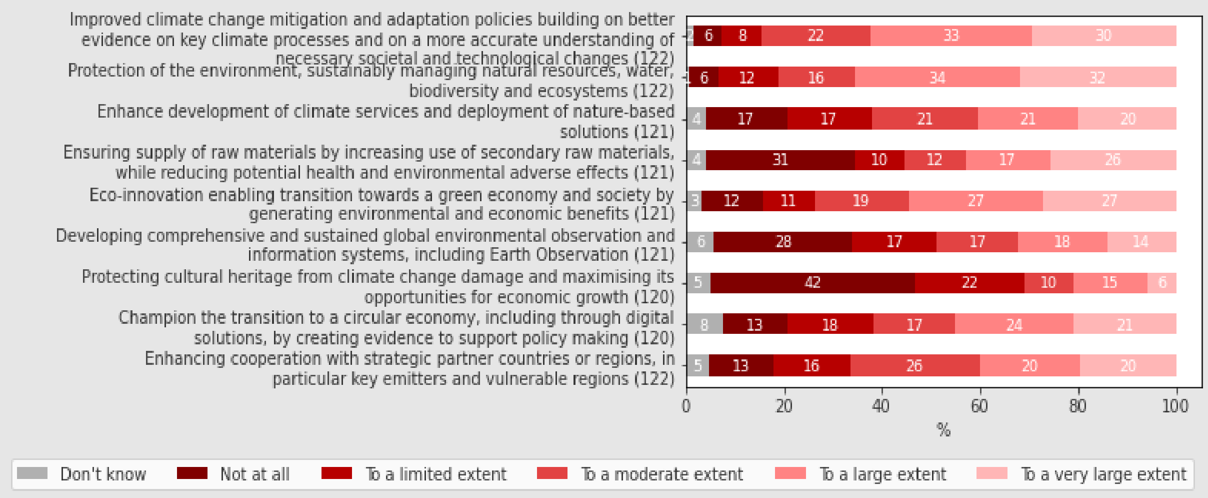


Figure 137 Q11: To what extent does your project address the following needs and challenges?

Collaboration

As pointed out previously, collaboration is a main motivational driver for H2020 participants. While the previous question was referring mainly to collaboration within the consortium, the one below targets collaboration with organisations outside the consortium. The intensity of collaboration was by far the highest with regards to research organisations (61% collaborated or co-led) followed by High Education Institutions (HEI) (55%). The lowest level of collaboration intensity was identified with regard to Research Funding Organisations (13%) and NGOs (13%).

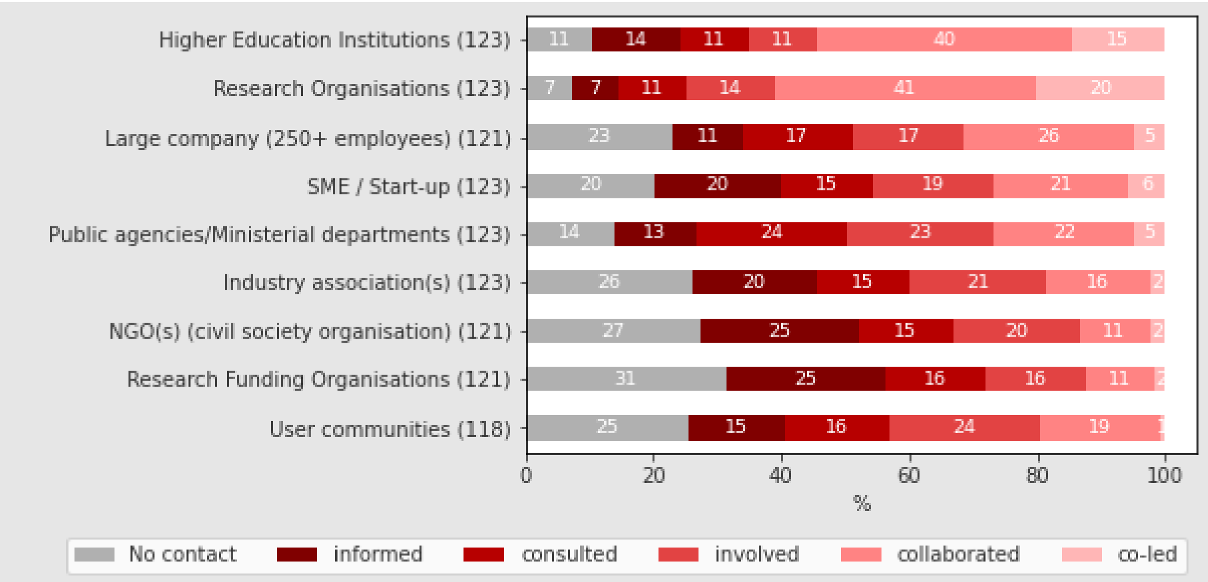


Figure 138 Q12: How intense was your collaboration with the following stakeholder groups outside the project consortium in the context of your project?

Some 65% of the respondents believed that all relevant stakeholder groups were addressed through the project activities. By responding 'Partially' the remaining 35% of the respondents believed that improvements were possible. Some of the recommendations for improvements are summarised after the table.

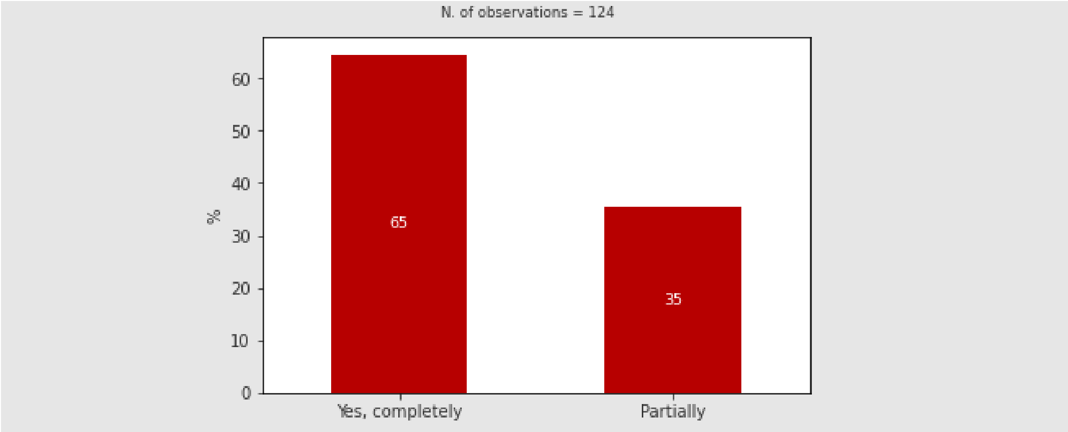


Figure 139 Q13: In your opinion, were all relevant stakeholder groups sufficiently addressed through the project activities?

Q14 Considerations with regards to stakeholder involvement:

- Respondents noted the importance of having a well-equipped outreach team and related communication channels that clearly communicate the scope, benefits, and outcomes to a variety of stakeholders.
- Conferences, events, fairs, webpages, social media, publications, public debates, and consultations all constitute meaningful communication channels. Varying the channels, also in scope and depth, for the sake of reaching different target audiences was found to be beneficial.
- Some respondents lamented disagreements in their consortia about when to begin involving stakeholders. As it was not agreed upon whether to develop a fully functional model before stakeholder engagement or build relationships early and consistently, outreach was significantly hindered. Various project with a co-design and co-production approach voiced their satisfaction with the levels of stakeholder engagement.
- Often time and resources limit the amount and types of stakeholders that can be involved. It was noted that reaching out equally to international, EU, national, local and community levels was a challenge. In some cases, this resulted in a notable imbalance between the types of stakeholders involved.
- In some cases, stakeholders did want to be engaged. Where stakeholders were correctly identified and contacted, their active participation remained challenging.
- The effects of the ongoing COVID-19 pandemic hindered both outreach to and successive engagement of stakeholders.
- A respondent noted that stakeholder contact, and engagement broke off entirely after the projects end. They voiced the need for the EU to support post-project activities with a minor presence or a higher focus on building sustainable structures before a project ends.

In addition, it should be pointed out that 52% of the respondents indicated that they have collaborated with non-European partners within the project.

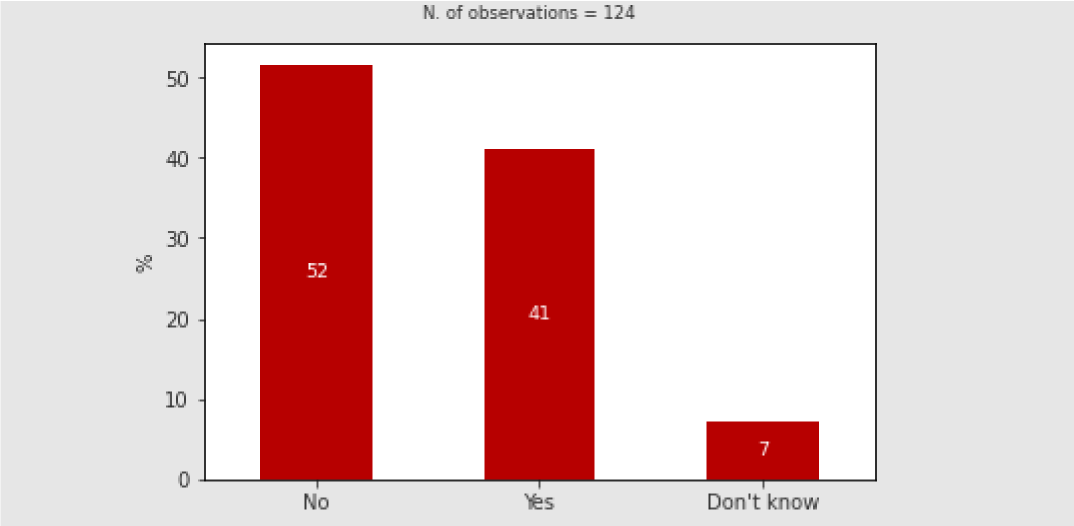


Figure 140 Q15: Have you collaborated with non-European partners as project partners in your project?

Those who collaborated with non-European partners pointed to several major benefits of this collaboration. ‘Development of know-how’ is the biggest identified benefit (68% - to a large or very large extent) followed by ‘Development of new, additional partnerships’ (64%). ‘Access to new markets’ and ‘Reduction of the environmental impact of the organisation’ have been the two smallest benefits (22% and 26% respectively).

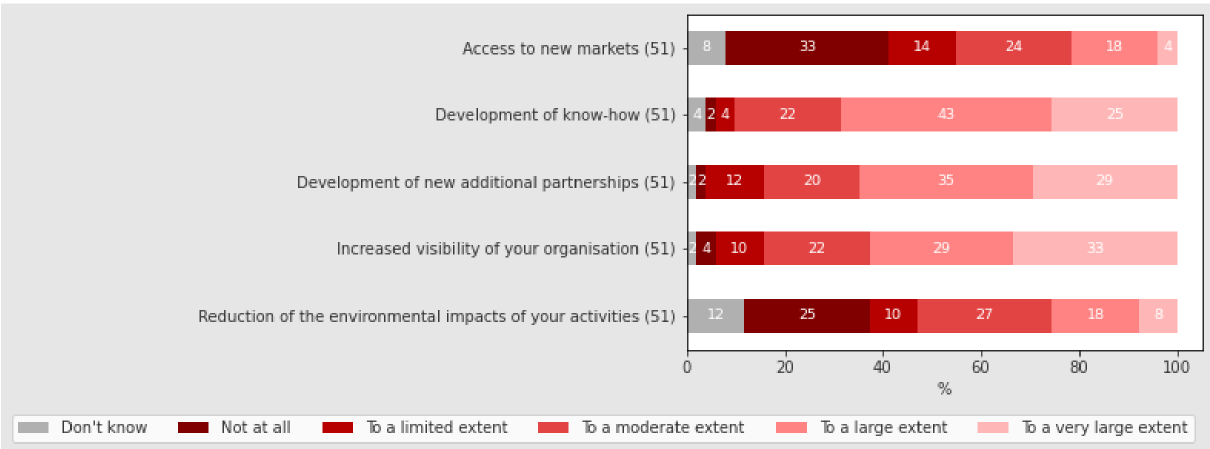


Figure 141 Q16: To what extent have you experienced the following benefits from the international cooperation in your project?

It has to be pointed out that some 44% of the respondents consider that cooperation with non-European partners contributes to a large or very large extent to improving the European position in the global competition. Some 33% think this advancement is to a moderate extent. Some 12% think it is to a limited extent while the remaining 12% either don’t know or think it is too early to tell.

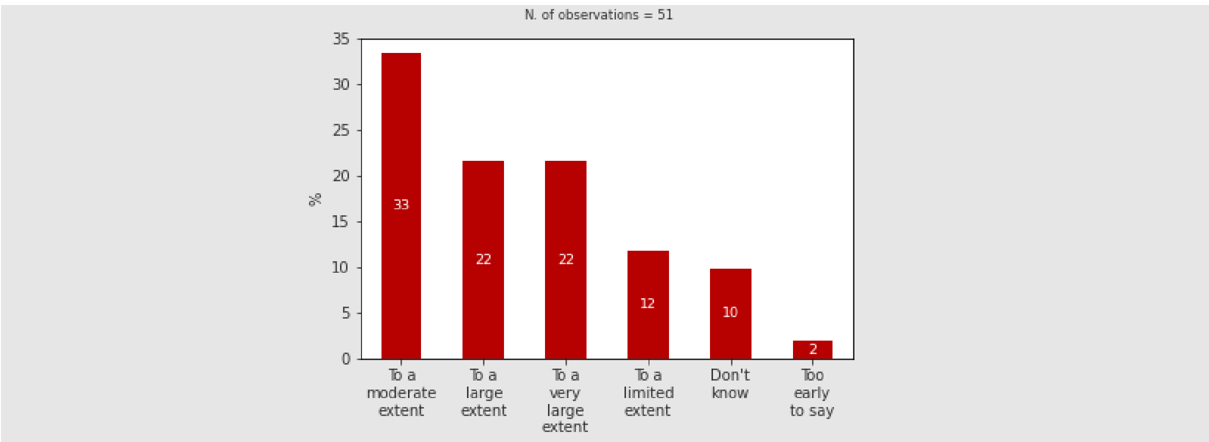


Figure 142 Q17: Has the cooperation with non-European partners in H2020 contributed to improving the European position in the global competition?

2.4.2. Effectiveness of the intervention

Results of the intervention

The answers to the survey revealed a high level of alignment between the objectives of the projects and their results. Some 84% of the respondents considered that these are fully aligned or aligned to a large extent. For 2% of the respondents, they are aligned to a limited extent.

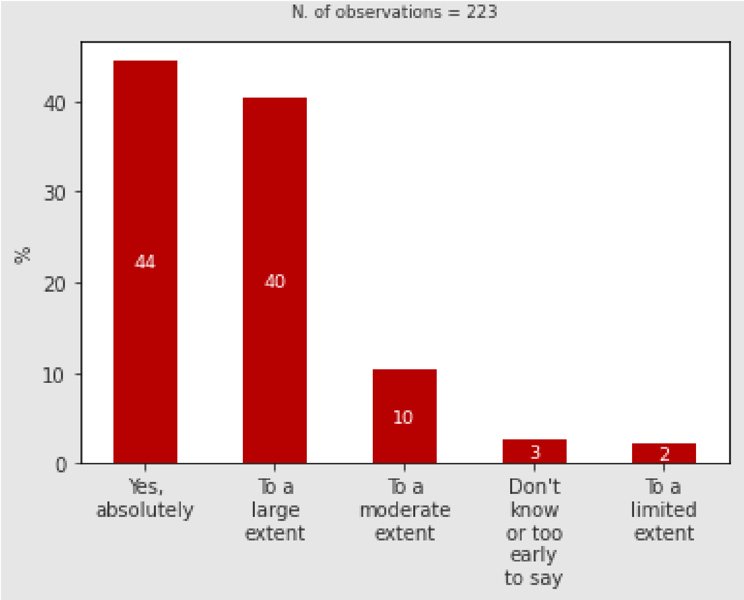


Figure 143 Q6: Are the results of your project in line with its objectives?

Between 28% and 72% of the respondents assess that the project contributed to a large or very large extent to the improvement of different aspects of expertise.

'Contribution to knowledge and capacity building' and 'Contribution to scientific and technological development' stand out as the aspects of expertise which have been improved to a large or very large extent (72% and 69%).

'Contribution to market and business development' is the expertise component which has been improved to the lowest extent as only 28% of the respondents consider that it has been improved to a large or very large extent.

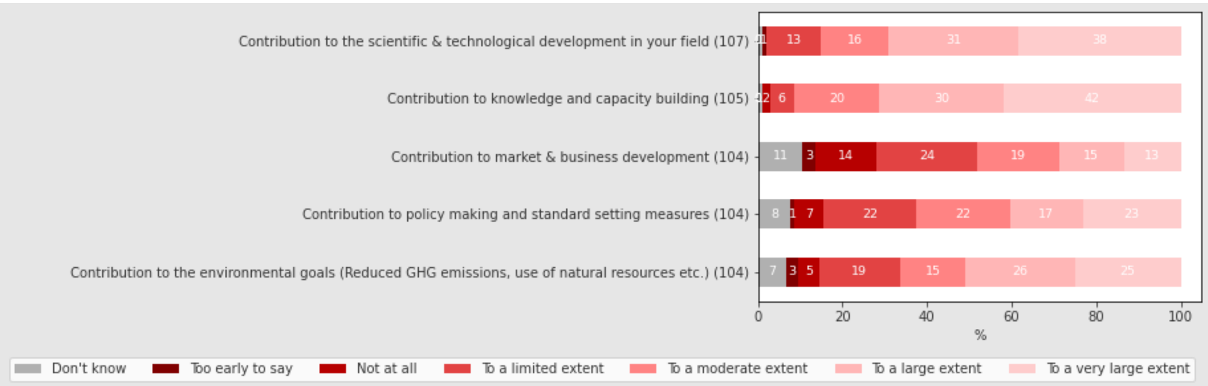


Figure 144 Q29: How successful was your project in terms of contributing to the following dimensions in your area of expertise:

Scientific results

Between 60% and 78% of the respondents assess that different scientific results have been fully achieved or achieved to a large extent. 'Better understanding of the subject' stands out as the scientific result which has been achieved to the highest extent (78%). It is followed by 'Better access to state-of-the-art research' (70%), 'Publications in peer-reviewed journals' (66%).

There is no (anticipated) scientific result which stands out with a low extent of achievement, the lowest being 'Researchers trained' with 60%.

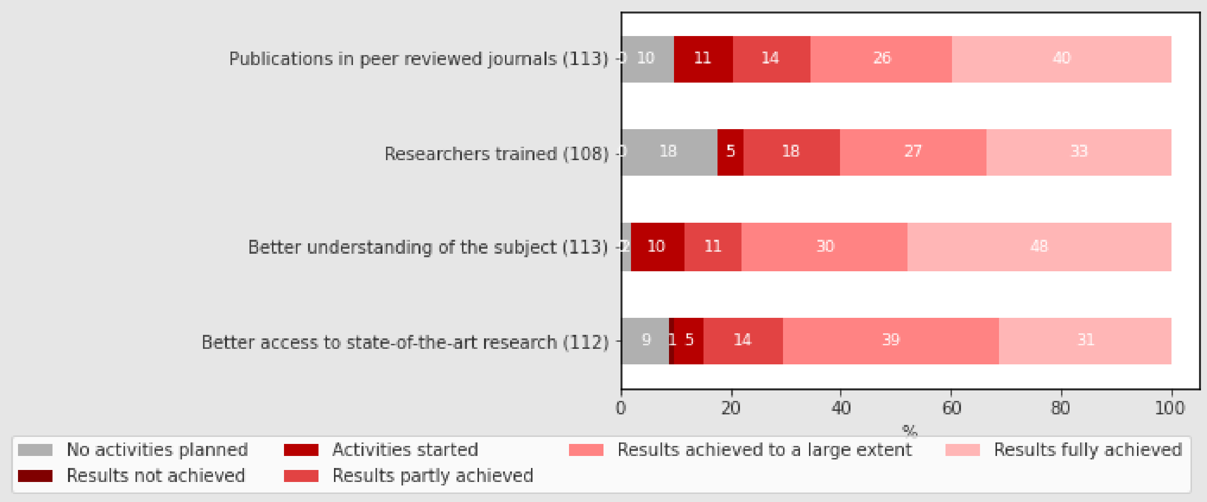


Figure 145 Q18: In terms of scientific outputs, what are the (anticipated) results of your project?

Technology and Innovation

Between 19% and 72% of the respondents assess that the technological development results have been fully achieved or achieved to a large extent.

'Expansion of basic knowledge for technological development', ‘New databases, platforms and test beds’, and 'New research tools, models, simulations' stand out as the technological development result which has been achieved to the highest extent (63%, 64%, and 72%).

'Increasing the safety of technologies and components' and 'Cost reduction of technology' are the anticipated technological development results which stand out with a low extent of achievement (full or to a large extent) (19% and 20% respectively).

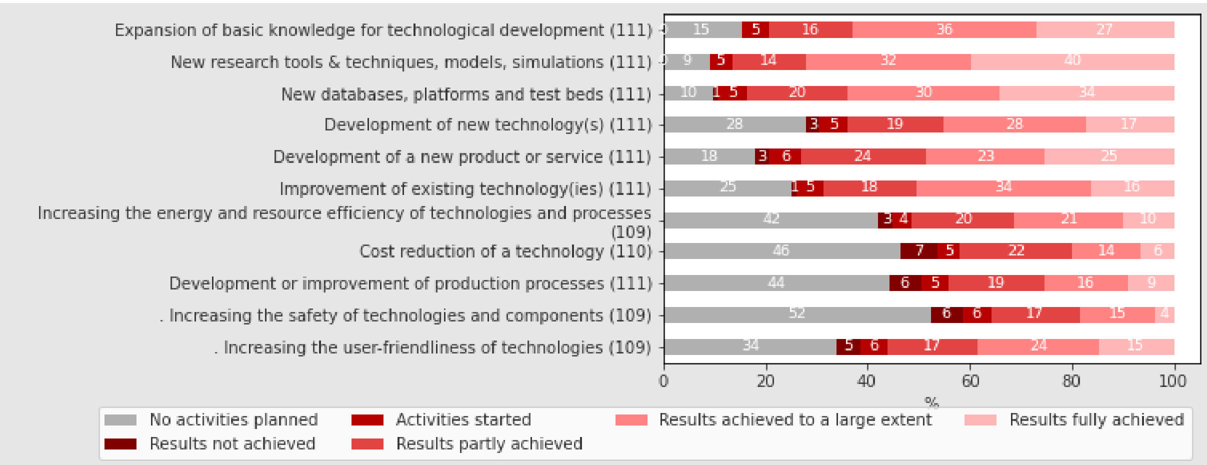


Figure 146 Q19: In terms of technological development outputs, what are the (anticipated) results of your project?

In terms of the contribution of the project to H2020 desired outcomes in Technology and Innovation, the respondents identified 'New or improved technologies and services accelerating transformation towards climate neutrality' and 'Strengthened eco-innovative technologies, processes and services' as the biggest achievements (52% and 43% respectively think that their projects contributed to these outcomes to a very large or large extent). On the other side of the spectrum, the outcomes achieved to the least extent are ‘New or improved solutions for preservation and management of cultural heritage at risk from climate change’.

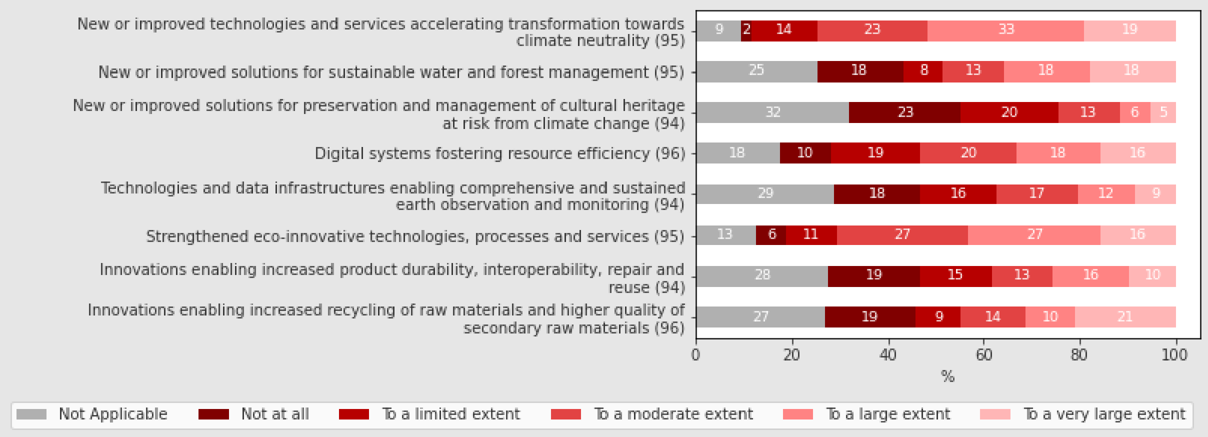


Figure 147 Q30: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Technology and Innovation.

Between 18% and 57% of the respondents assess that the system development results have been fully achieved or achieved to a large extent.

'Demonstrate or pilot feasibility of technological solutions', ‘Development of proposals for the further development of technological systems’, and ''Integration of technology’ are the system development result which has been achieved to the highest extent (57%, 43% and 43%, respectively).

'Developing innovations in marketing and sales', 'Developing of organisational innovations' and 'Developing of social innovations' are the anticipated system development results which stand out with a low extent of achievement) (18%, 20% and 26% respectively think they have been achieved fully or to a large extent).

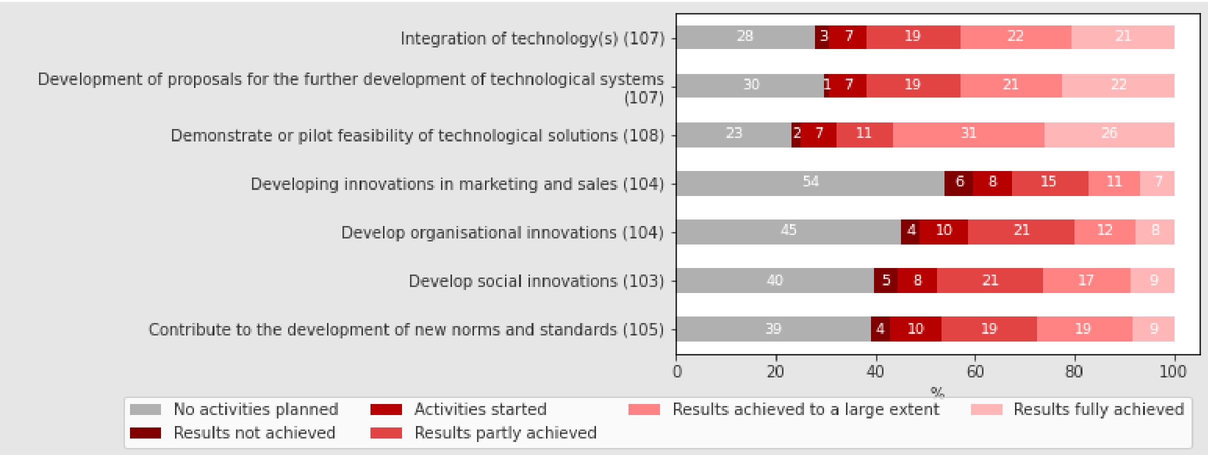


Figure 148 Q21: In terms of system development, what are the (anticipated) results of your project?

With regards to Technology readiness a significant share of the respondents (23%) currently considers that the TRL concept be applied to their project.

Initially, more than one-fifth of the respondents (28%) consider their overall TRL level was 2, currently only 9% consider it to be at that level. The second biggest development in the initial TRL level to the current TRL level can be seen for TRL 3, which shows a change from 19% to 7%. For TRL 4 this change is from 15% to 23%. Also, levels 6 and 7 show relatively high changes, from 2% to 6% and 2% to 9%, respectively.

While it is difficult to gauge the progress within the same project, we observe that the overall level of the TRL has increased across the board.

An additional analysis was done regarding the distribution of types of actions. This showed that for the highest percentage of CSA projects, the TRL was not applicable. IA projects were found to be mainly in a high TRL stage. For RIA projects most projects were in low TRL stages.

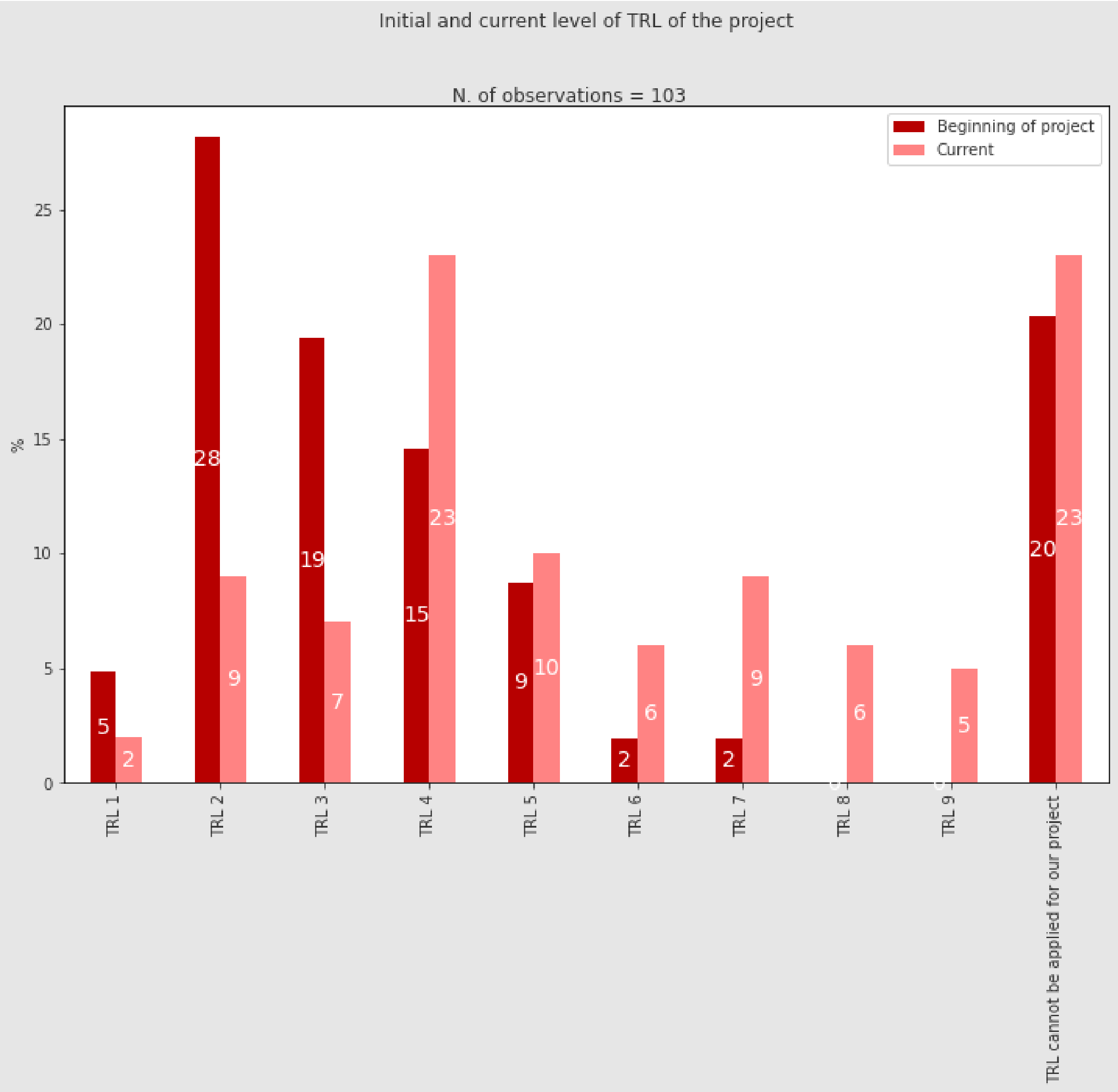


Figure 149 Q22: What was the overall level of Technology-Readiness at the beginning of the project (TRL)? And Q23: What is the current overall level of Technological-Readiness of your project's technological development?

While 23% of the respondents consider that the TRL concept is not relevant to their project, almost one-fourth had TRL 4 as a target technology readiness level. Very few aimed at lower TRLs (13%). TRL 5 was the answer for 10% of the respondents and the share goes down for higher TRLs.

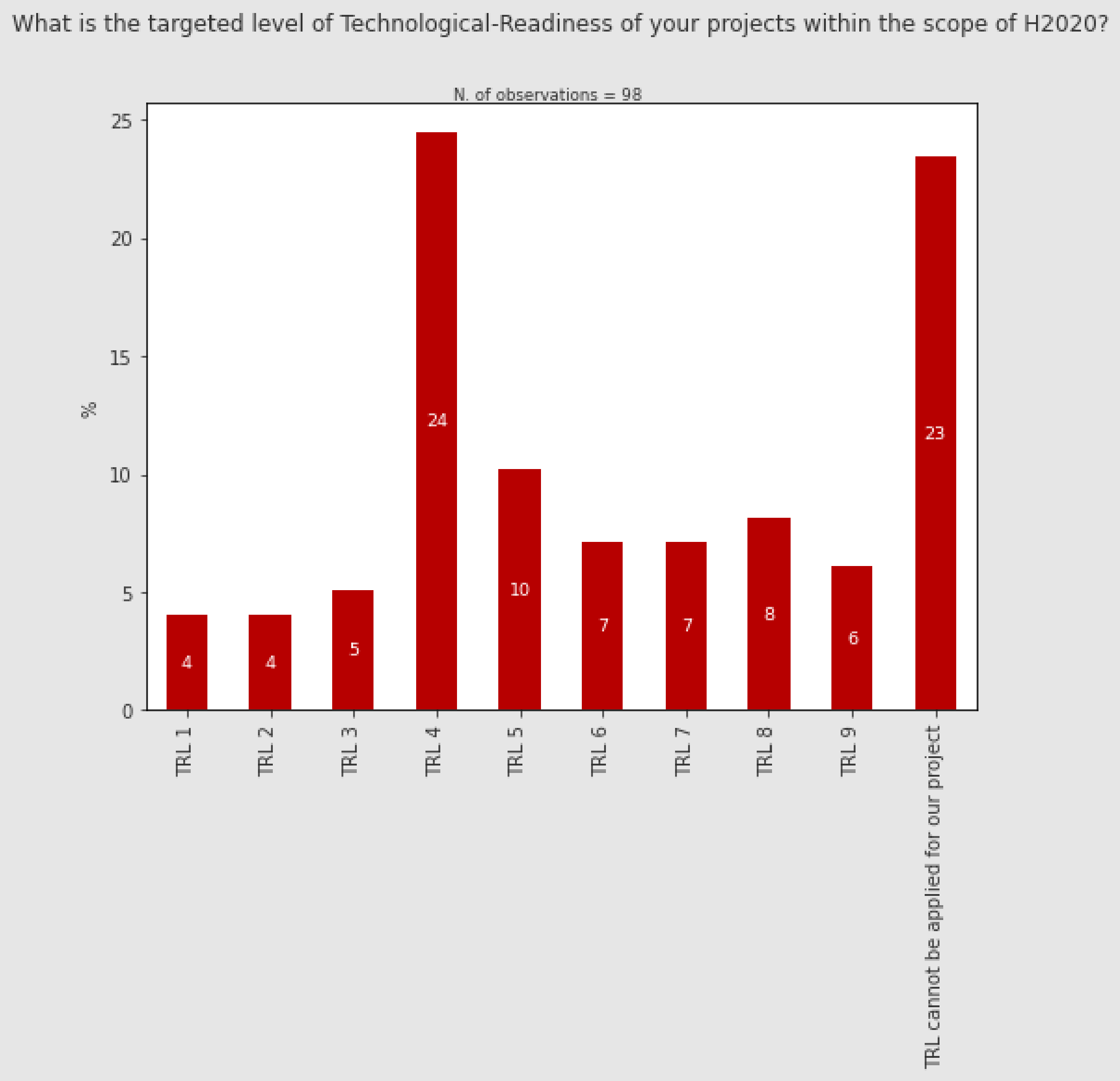


Figure 150 Q24: What is the targeted level of Technological-Readiness of your projects within the scope of H2020?

Knowledge and Capacity

Between 33% and 63% of the respondents assess that the project influenced their organisation to a large or very large extent.

'Increased focus on interdisciplinary research' and 'Increased attention for the needs of society' are the two aspects for which the project has influenced the organisations to a large and very large extent (63% and 60%).

'Increased focus on risk-oriented research', is the aspect of the organisation which stand out as influenced the least. 33% of the respondents thought it had been influenced to a large or very large extent.

Figure 151 Q26: To what extent did your project influence the following aspects of your organisation?

With regard to the contribution of the project in terms of enabling several desired outcomes. 'Strengthening R&I capacities in your area' and 'EU excellence in science and innovation' stand out as the two outcomes achieved to the largest extent (66% and 62% respectively). The two desired outcomes which have been achieved to the lowest extent are 'Improved dissemination of knowledge on climate change to low-and middle-income countries' (30%) and 'Increased understanding of ecosystems, their interactions with social systems and their role in sustaining the economy and human wellbeing' (34%).

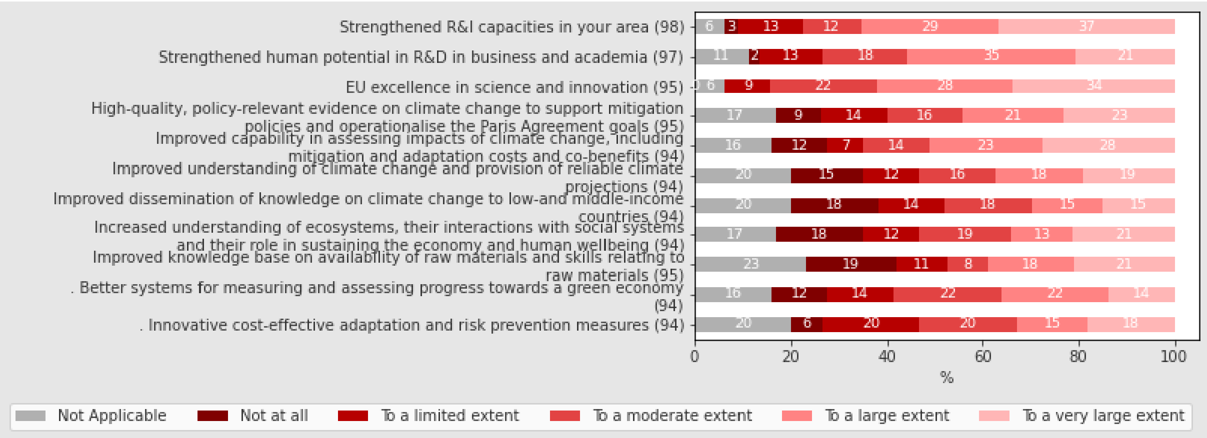


Figure 152 Q31: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Knowledge & Capacity.

Coordination and collaboration

Between 20% and 68% of the respondents considered that their projects contributed to the different desired outcomes of Horizon 2020.

The first four outcomes have been achieved almost to an identical extent at around 63-68% of the respondents considering the contribution to be to a large or very large extent. 'Improved participation and financial contributions to multilateral processes' stands out as the outcome to which projects have contributed the least (20%).

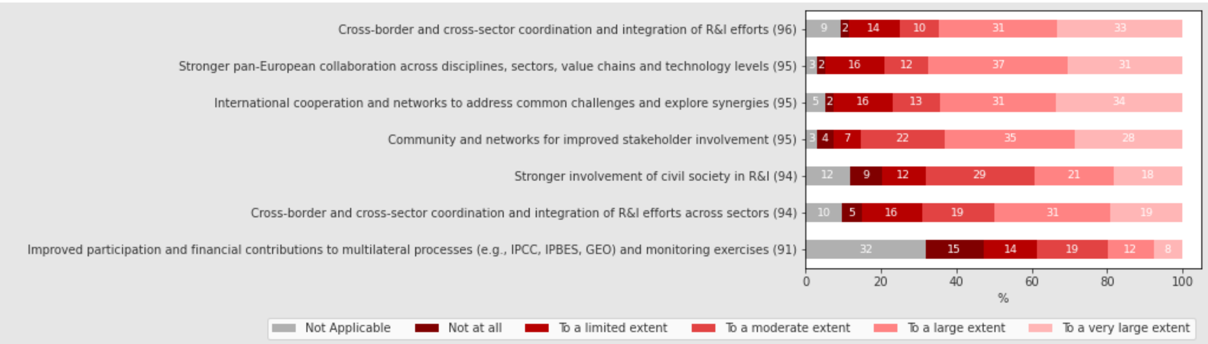


Figure 153 Q32: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Coordination & Collaboration.

Markets and business

Between 5% and 36% of the respondents assess that the market development results have been fully achieved or achieved to a large extent.

'Development of marketable products or services' is the market development result which has been achieved to the highest extent (36%).

'Creation of a start-up' and 'Creation of a spin-off', are the anticipated market development result which stand out with a low extent of achievement (full or to a large extent) (8% and 5% respectively).

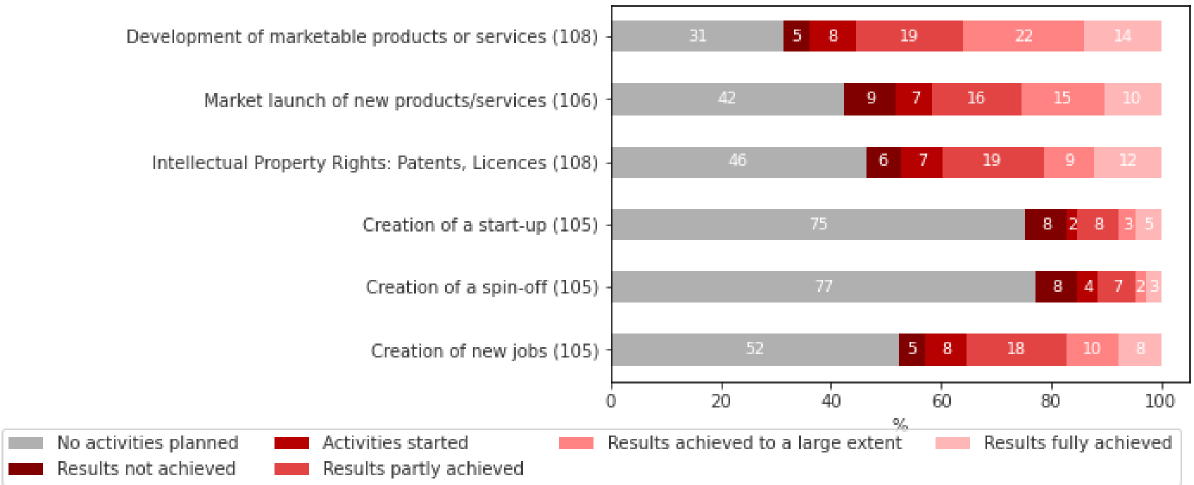


Figure 154 Q20: In terms of market development, what are the (anticipated) results of your project?

Some 32% of the respondents think that the project has contributed to a large or very large extent to the improvement of the time-to-market of technological solutions. Inversely, 20% consider that this has happened to a limited extent (13%) or not at all (7%). Some 26% of the respondents are not aware of the effect of the project on the 'time-to-market' of new solutions.

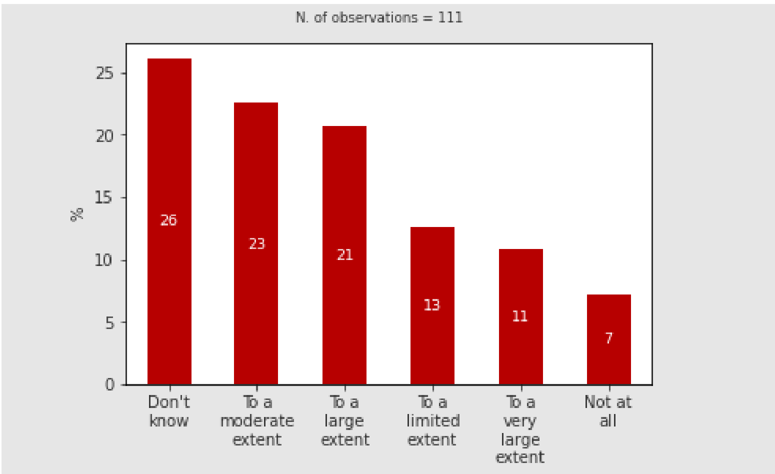


Figure 155 Q25: Has the project contributed to improve the "time-to-market" of new solutions?

No more than 10-11%% of the respondents consider that the project led to a 20% or more increase in turnover (11%), employment or profit (both 10%). Between 19% and 29% of the respondents think that there has been an incremental increase between 1% and 20% for these three aspects. Between 60% and 70% of the respondents either don't know if there has been an increase in these three aspects or think that there has been no change. There is only a small difference between the answers with regard to the different economic benefits. Profit is the one which is considered to be the least impacted with 70% who either do not know or think there has been no change. From those who think there have been economic benefits, the majority consider an incremental increase between 1-10% for all impacts.

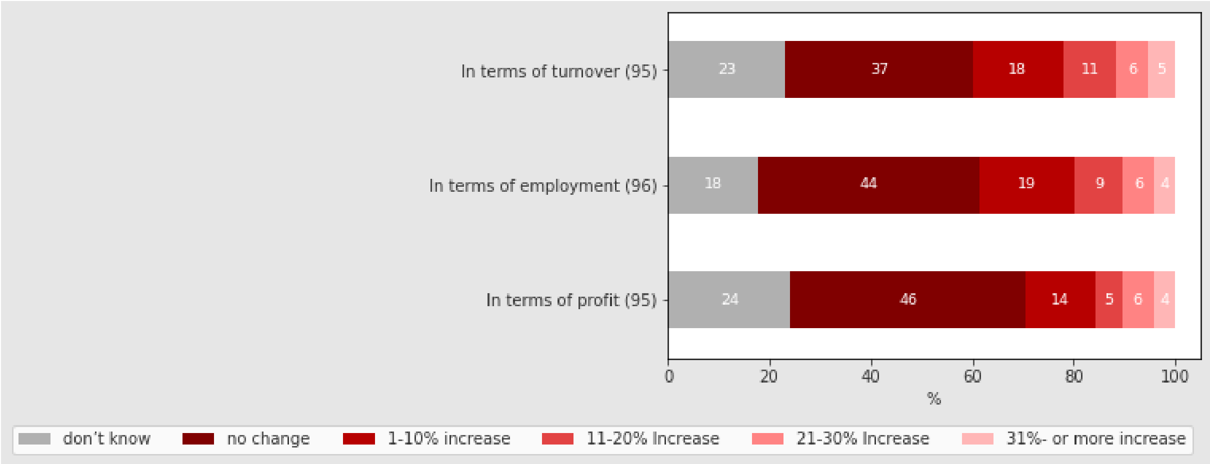


Figure 156 Q27: To what extent has your participation in H2020 led to the following economic benefits (or is it expected to do so after project completion) in your operational unit? Please provide best estimates.

Between 34% and 48% of the respondents assess that the project influenced their competitiveness to a large or very large extent: nationally (48%), in Europe (39%) or internationally (34%). Around 19-30% think that the increase has been to a moderate extent. Between 15% and 26% of the respondents either don't know or think that the project influenced their competitiveness nationally, in Europe or internationally not at all or to a very limited extent.

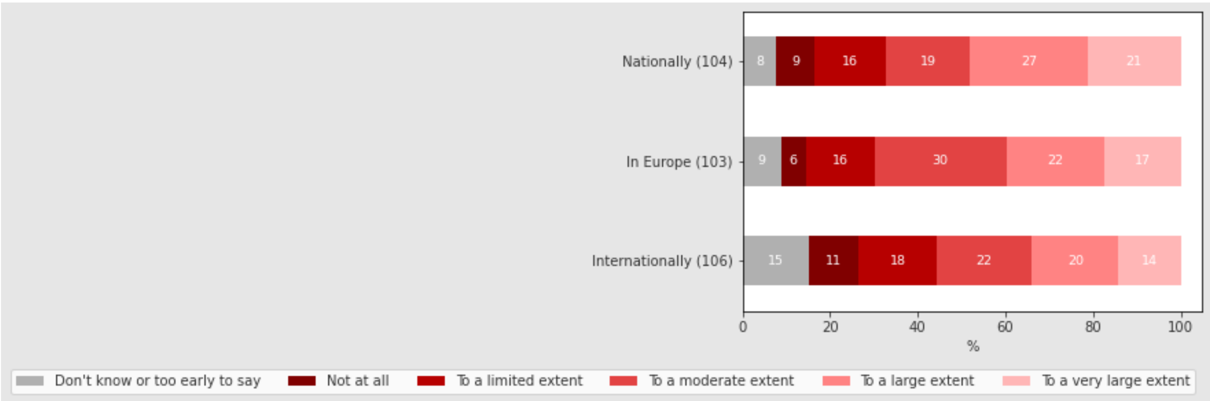


Figure 157 Q28: Do you consider that your project contributed to the increase of the overall competitiveness of your operational unit?

Between 20% and 26% of the respondents think their project contributed to a large or very large extent to the different desired outcomes. The share is the highest for the outcome 'Higher consumer awareness and acceptance (26%) followed by 'Increased investment in and market uptake of eco-innovation' (25%), followed by 'Increased efficiencies from enhanced supply, use and re-use of secondary raw materials' (23%). All other outcomes have the same positive response of 20%. It has to be noted that a significant portion of the respondents think the contribution has been moderate.

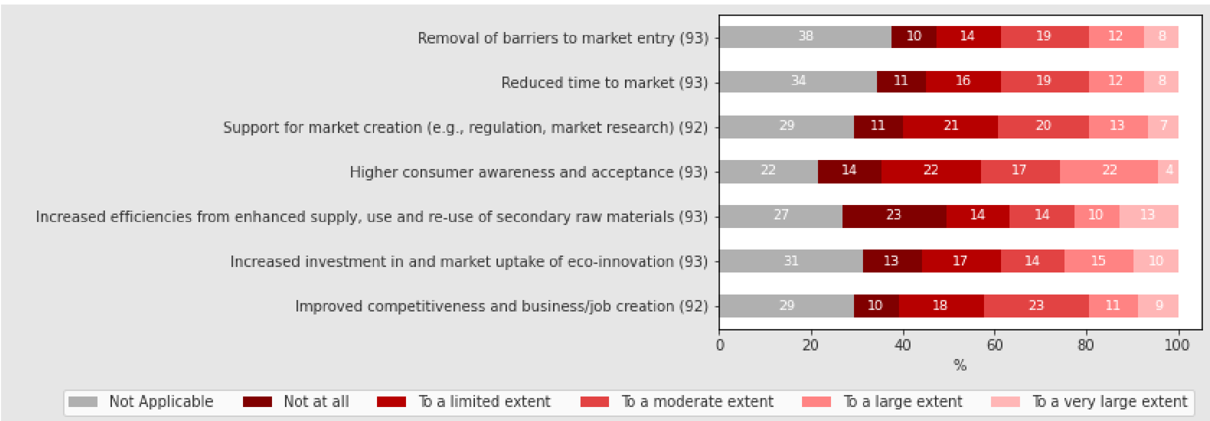


Figure 158 Q33: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Market & Business.

Policies and standards

Between 25% and 42% think the projects contributed to the desired outcomes in terms of policies and standards. 'More robust and transparent policy-making' comes first with 42% of the respondents while 'Improved use of existing climate- and water-related Earth Observation data for policy-making' and 'Improved decision-making on climate change adaptation options, disaster response and water management' come last with 25% and 27% respectively.

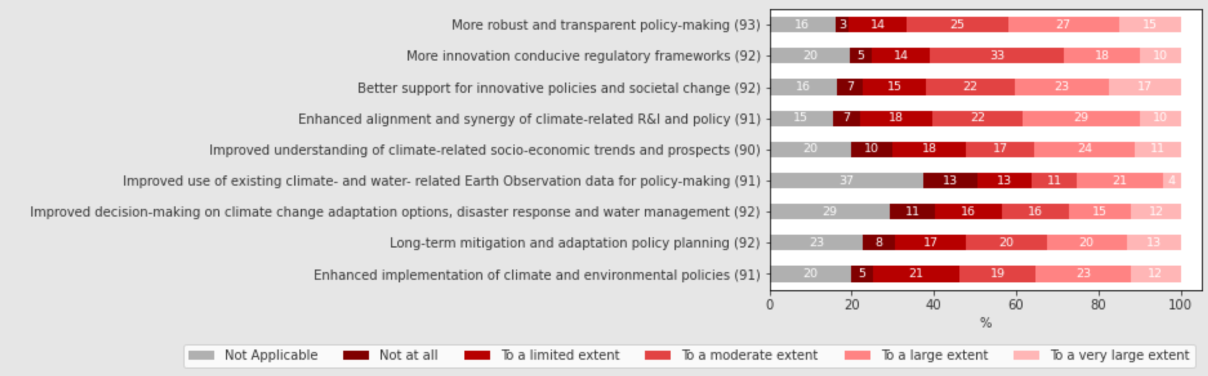


Figure 159 Q34: To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Policies & Standards.

Barriers and enabling factors

Between 14% and 30% of the respondents consider that different types of barriers impede the successful uptake of their projects to a large or very large extent. The two barriers which stand out are ‘Limited financial resources for the implementation of project results’ (30%) and ‘Lack of internal organisational support for implementation’ (25%). If respondents who chose that the influence is moderate are added to the figures, then ‘Lack of suitable skilled personnel’ is also tangible with 41%. Overall, all the mentioned barriers are valid.

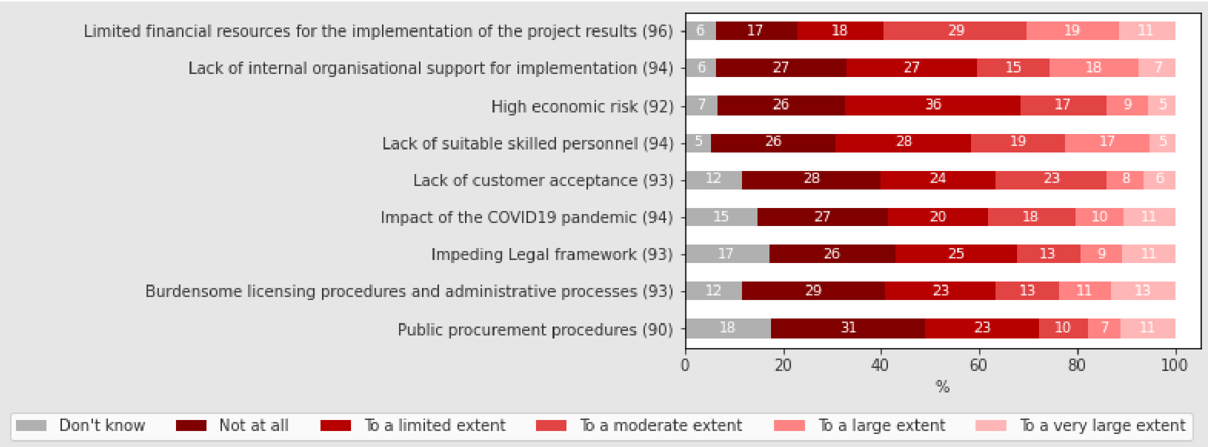


Figure 160 Q35: Barriers and enabling factors: Do you see barriers that impede a successful uptake of results of your project?

Dissemination, exploitation and communication

The huge majority of respondents think that dissemination, exploitation and communication activities have been both useful (76% to a large and very large extent) and sufficient (68%). Less than 4% don’t know or consider that they have been neither useful nor sufficient.

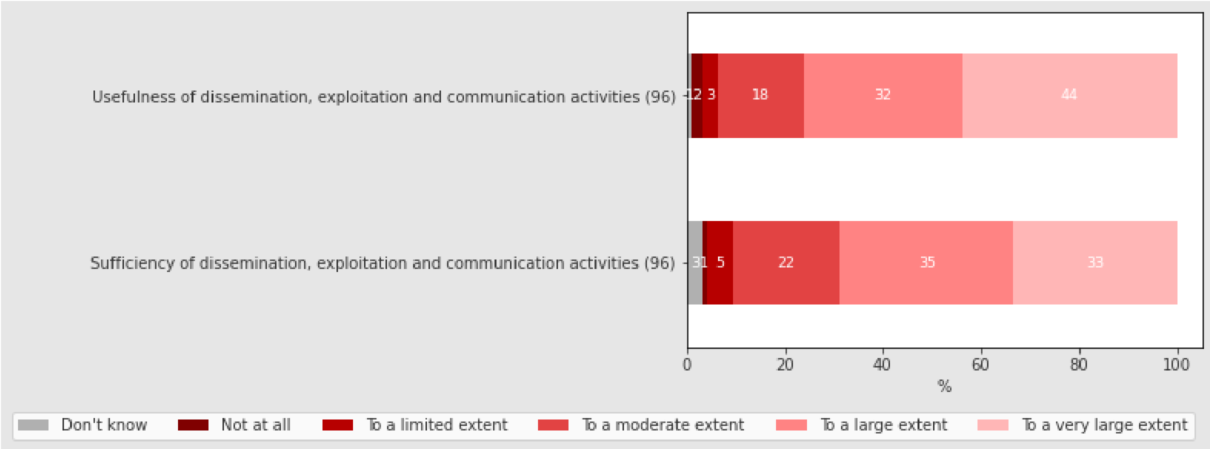


Figure 161 Q36: To which extent have the dissemination, exploitation and communication activities been useful and sufficient in the uptake of your project results?

2.4.3. EU added value

Between 50% and 85% of the respondents think that H2020 provided an EU-added value in several aspects to a large and very large extent. The aspects of 'Size of the project budget' and 'Funding opportunities for specific topics' come first with 85% and 83%, respectively. The lowest value added is on technical support provided (50%) and 'More possibility to conduct fundamental, exploratory or risky research (55%).

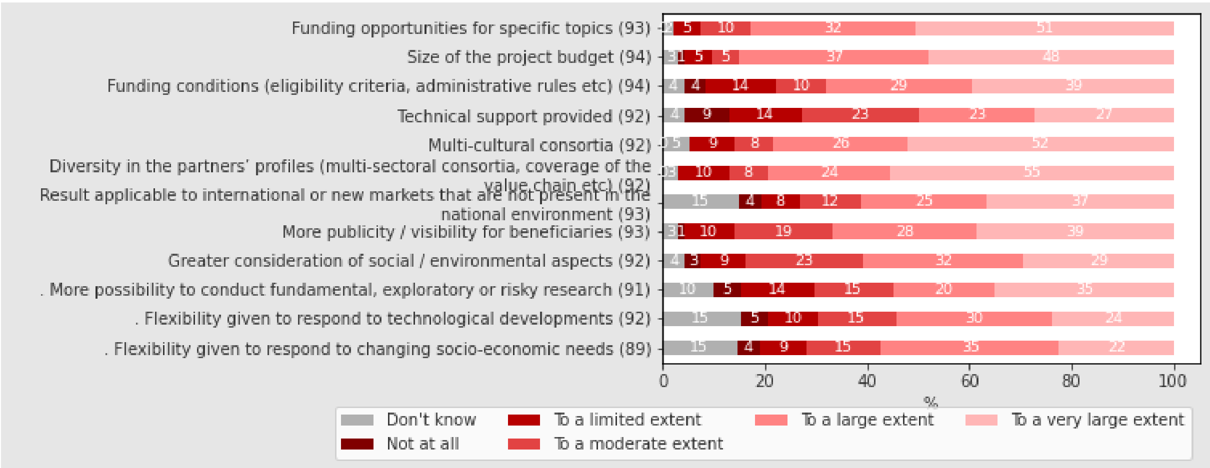


Figure 162 Q50: To what extent do you see added value from funding Horizon 2020 projects compared to funding on a national or regional level?

Some 73% of the respondents answered that the project would not have been implemented; 76% - the scope would have been reduced; 46% that it would have been implemented with other partners; 14% that it would have been funded on a national or regional level; 34% that its timeline would have been extended; and 40% that it would have been delayed.

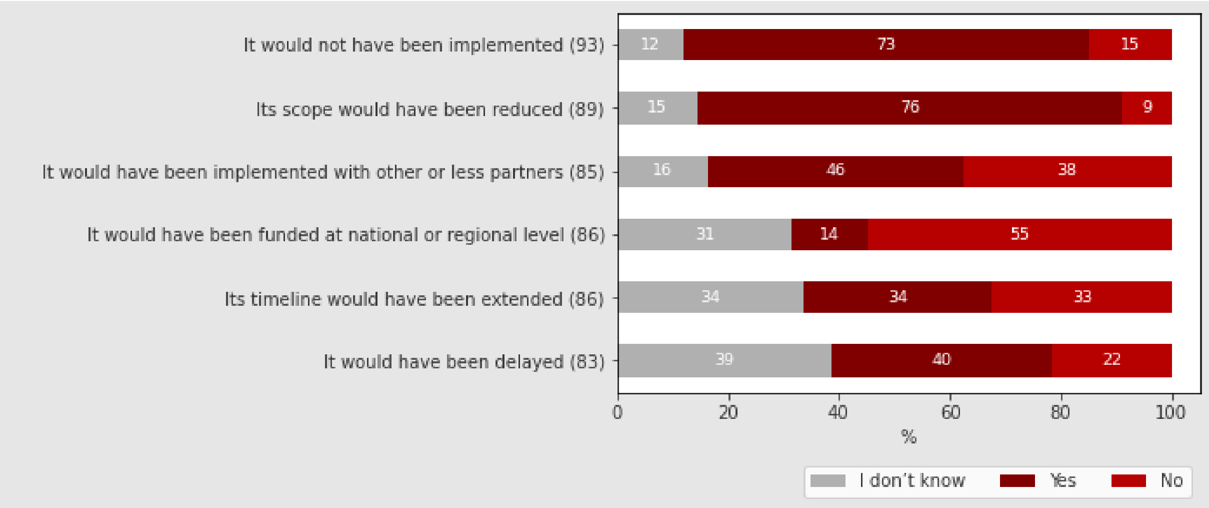


Figure 163 Q51: Without support from H2020, what would have happened to your project?

2.4.4. Summary

Relevance and coherence

In terms of technology and innovation, the two main **motivational drivers** for respondents are 'addressing specific scientific or technical questions, problems and issues' and 'development of new processes, products and services'. 'Accessing funding for seed research' did not appear to be of the same importance. As far as climate and environment are concerned, 'increasing resource efficiency in processes' and the need 'to address grand societal challenges related to climate' were the biggest motivators for participation in the Framework Programmes. From a business and competitiveness point of view, 'improving the visibility of the organisation' exceeded significantly other motivational factors such as 'increasing the productivity and competitiveness of the organisation' and 'diversification of the organisational activities'. Collaboration is a strong driver for participation in FPs, especially the 'development of new collaborations with other types of organisations' and much less so 'developing collaborations with non-EU organisations' and 'sharing the risks of a project'.

The needs and challenges of projects have been addressed to varying extents. '*Protection of the environment, sustainably managing natural resources, water, biodiversity and ecosystems'* has been addressed to the highest extent. The challenges and needs which have been addressed to the lowest extent are 'Protecting cultural heritage from climate change damage and maximising its opportunities for economic growth' and 'Developing comprehensive and sustained global environmental observation and information systems, including Earth Observation'.

Collaboration is key for H2020 projects, and its intensity was the highest with *Higher Education Institutions* and *Research Organisations* which exceeded by far collaboration with other types of stakeholders. On the other end of the spectrum, collaboration was lowest with *NGOs* and *Research Funding Organisations*.

With regards to **involving stakeholders** in the work of the projects, 35% considered this to be done only partially. It was noted that having a well-equipped outreach team was a barrier to involving stakeholders effectively. Also, Covid-19 was a major reason. Varying the communication channels, also in scope and depth, for the sake of reaching different target audiences was found to be beneficial to reach stakeholders.

Collaboration with non-EU partners took place for less than half of the respondents but those who collaborated saw benefits from it the main one being *the 'development of know-how'*. *'Access to new markets'* has not been identified as a major benefit. Respondents are split with regards to the contribution of cooperation with non-EU partners on European position in global competitiveness: 44% considered this to be the case to a large and very large extent; one-third thought the impact was moderate and 12% either did not know or were sceptical about that.

Effectiveness

According to survey responses, there is a high level of alignment between project objectives and results. From a **knowledge** perspective, the project contributed to the largest extent to *'knowledge and capacity building'* and *'scientific and technological development'*. *'Contribution to market and business development'* has been the lowest. In terms of **scientific results**, respondents consider that the project contributed to the largest extent to a *'better understanding of the subject'* and *'better access to state-of-the-art research'.*

With regards to **technology and innovation**, 'New research tools, models, simulations' and 'New databases, platforms and test beds' are the two technological development results which have been achieved to the highest extent. 'Cost reduction of technology' and 'increasing technology safety' have been achieved to the lowest extent. In terms of technological development outputs, the respondents identified 'New or improved technologies and services accelerating transformation towards climate neutrality' and 'Strengthened eco-innovative technologies, processes and services' as the biggest achievements. **System development results** are considered as achieved fully or to a large extent by 18% to 57% of the respondents. 'Demonstrate or pilot feasibility of technological solutions', 'Development of proposals for the further development of technological systems', and ''Integration of technology' are the system development result which has been achieved to the highest extent. However, different types of innovations in marketing and sales are on the low end.

The **TRL concept** has not been considered relevant by almost one-quarter of the respondents. The technology readiness for almost half of the projects was TRL2 and TRL3 at the start of the project. 15% were TRL4 and TRL5 while 13% were TRL6 and higher. The overall TRL levels at the end of the projects reveal a significant increase in levels although data does not allow comparison between TRL levels at the start and the end of the same project.

Organisational knowledge has been influenced to a large and very large extent for 33%-63% of the respondents, the largest focus being on 'increased focus on interdisciplinary research'. At the same time 'Increased focus on risk-oriented research' has been influenced by the least respondents.

With regards to **coordination and collaboration**, four of the outcomes have been achieved to a large or very large extent by two-thirds of the respondents. These include cross-border and cross-sectoral integration; stronger pan-European collaboration across sectors; networks to address common challenges; and community and networks for improved stakeholder involvement.

In terms of market and business, 'Development of marketable products or services is on the highest end while Creation of start-ups and spin-offs have been achieved to a large or very large extent by only 5-8% of the respondents. More than half of the respondents think the time-to-market of technological solutions has been improved. The impact of the project on the microeconomic bottom line – turnover, employment, profit - of the project is very limited. A slightly bigger share of the respondents believes the project improved their competitiveness, mostly in Europe and nationally and to a lesser extent – internationally. The relatively low level of perceived impact on market and business is also reflected in the perceived impact on different types of related outcomes. The outcome 'Higher consumer awareness and acceptance' has been achieved to a large and very large extent by almost one-third of the respondents.

In terms of policies and standards, desired outcomes have been achieved to a large and very large extent by 25-42% of the respondents. Key policy outcomes such as 'More robust and transparent policy making' have been achieved by around a third of the respondents.

Different barriers impede project uptake to a varying degree, limited financial resources being the biggest obstacle followed by 'Lack of internal organisational support for implementation'. It is positive that even for these two barriers the share of respondents hardly exceeds 30%.

The huge majority of respondents think that **dissemination, exploitation and communication** activities have been both useful (76% to a large and very large extent) and sufficient (68%).

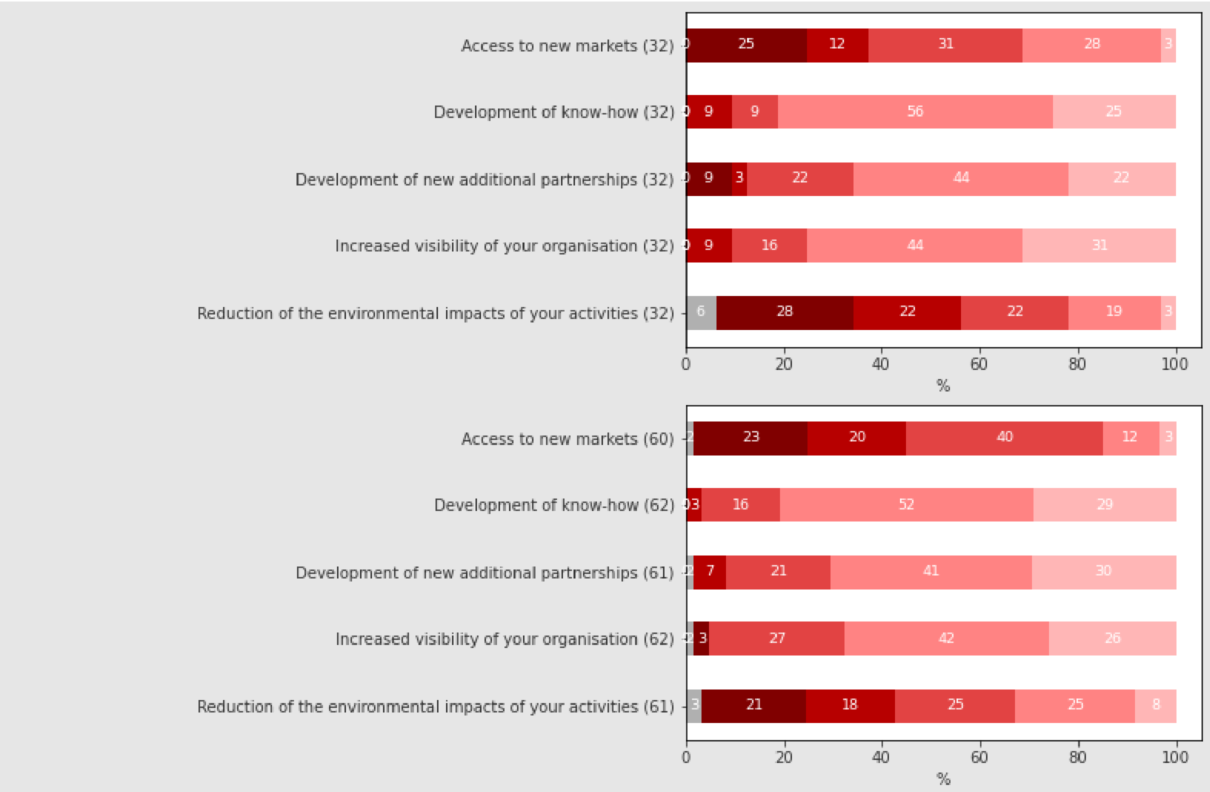
EU added value

Between 50 and 85% of the respondents think that H2020 provided an EU-added value in several aspects to a large and very large extent, especially in terms of the 'Size of the project budget' and 'Funding opportunities for specific topics'. To the least extent, it contributed to 'technical support provided'. 73% of the respondents answered that the project would not have been implemented without support from H2020.

2.5. Analyses per type of project

For questions 16, 20, 26, 29, and 51, additional analysis has been done to understand how the results differ per type of project as these questions are the ones which would be most affected by the type of project. For this purpose, only IA, CSA, and RIA types of projects have been included. Also, since the sample size of other project types where too low to be significant, the Art. 187 partnerships have been grouped.

Those projects which collaborated with non-European partners pointed to several major benefits of this collaboration. Across project types 'development of know-how' was identified as the greatest benefit, with 70% – 81% saying it contributed to a large or very large extent. Similarly, for all four types of projects, 'Access to New Markets' and 'Reduction of the environmental impacts of your activities' constitute the least common benefit. Overall, we note that there is no significant difference across project types.



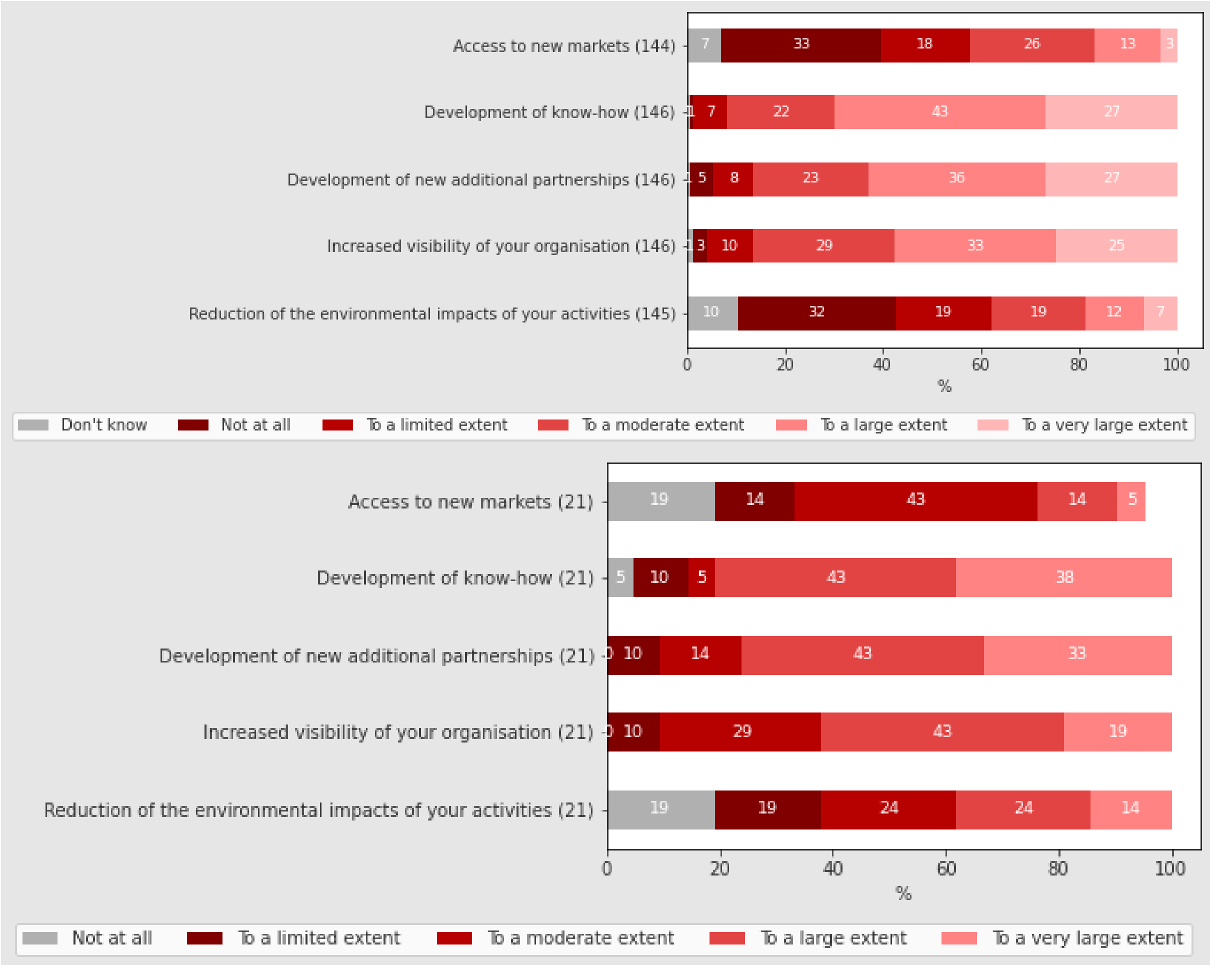


Figure 164 Q16: To what extent have you experienced the following benefits from the international cooperation in your project?' per type of project: IA, CSA, RIA, and Art. 187 partnerships from high to low.

'Development of marketable products or services' and 'Creation of new jobs' are the market development results which have been achieved to the highest extent in IA, CSA and RIA projects. Only for Art. 187 partnerships the second highest statement was different, namely the 'Market launch of new products/services'. Notably, in IA projects the first result is achieved by 50% of the respondents (large extent or fully achieved) compared to CSA and RIA projects (both 34%). For RIA projects, 'Market launch of new products' is an equally significant outcome as is 'Intellectual Property Rights, Patents and Licenses', both with (23%). In all four project types, the creation of spin-offs or start-ups is the anticipated market development result which stands out with the lowest extent of achievement (less than 6% fully or to a large extent).

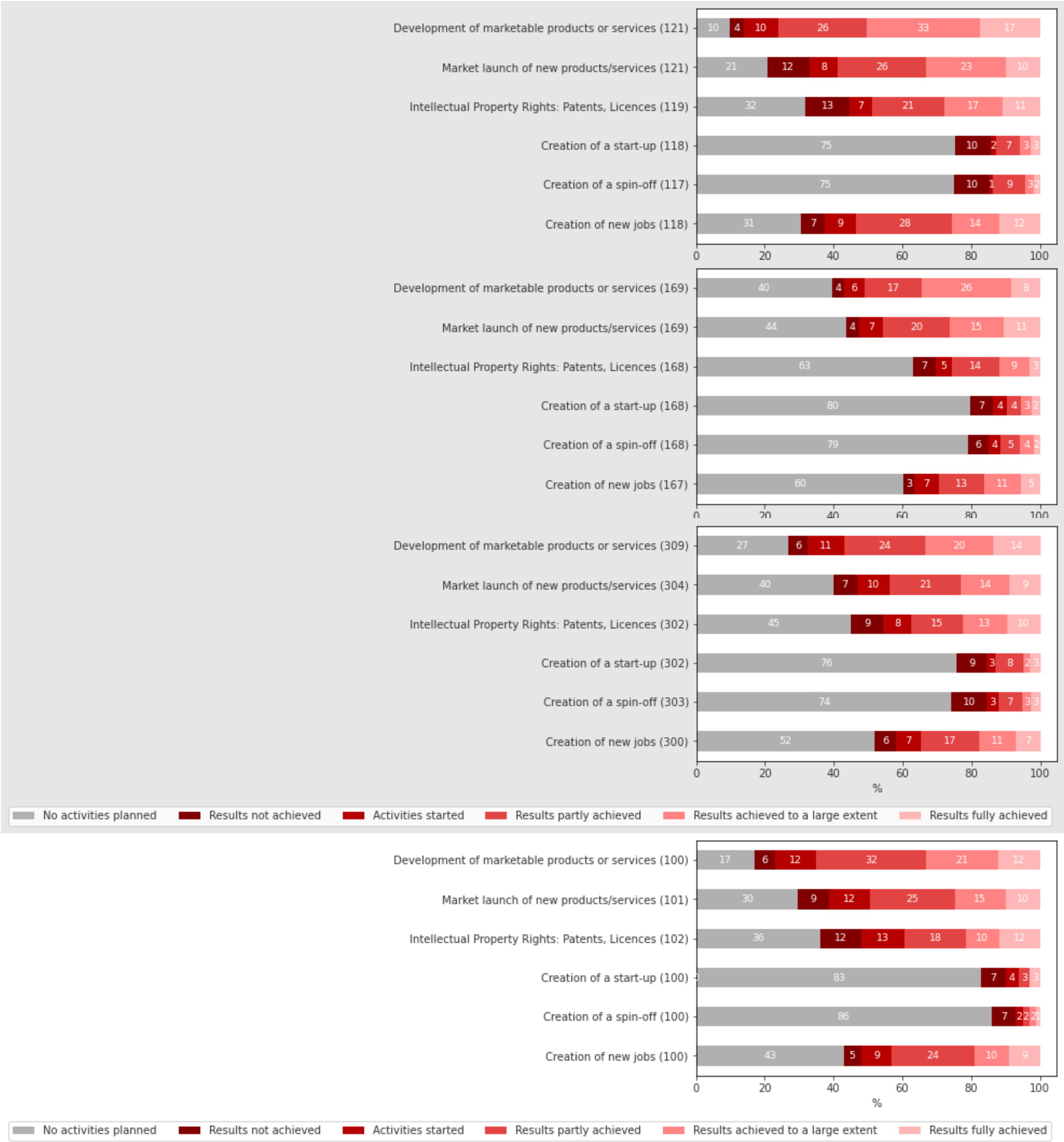


Figure 165 Q20 'In terms of market development, what are the (anticipated) results of your project?' per type of project: IA, CSA, RIA, and Art. 187 partnerships from high to low.

Regarding a project's influence on organisational aspects, there is some variety between types of projects, however, they mostly reflect similar trends. 'Intensification of R&D collaboration with new research organisations' is the most important aspect for both IA and RIA projects with 50% and 46% to a large or very large extent respectively, whereas for CSA projects this is 'increased attention for societal needs' (52%). For the Art.187 partnerships 'Increased focused on interdisciplinary research' was the highest ranked (52%). On the lower end of the spectrum, 'Increased focus on risk-oriented research' stands out as the least influenced aspect for all three project types (15-32% to a large or very large extent).

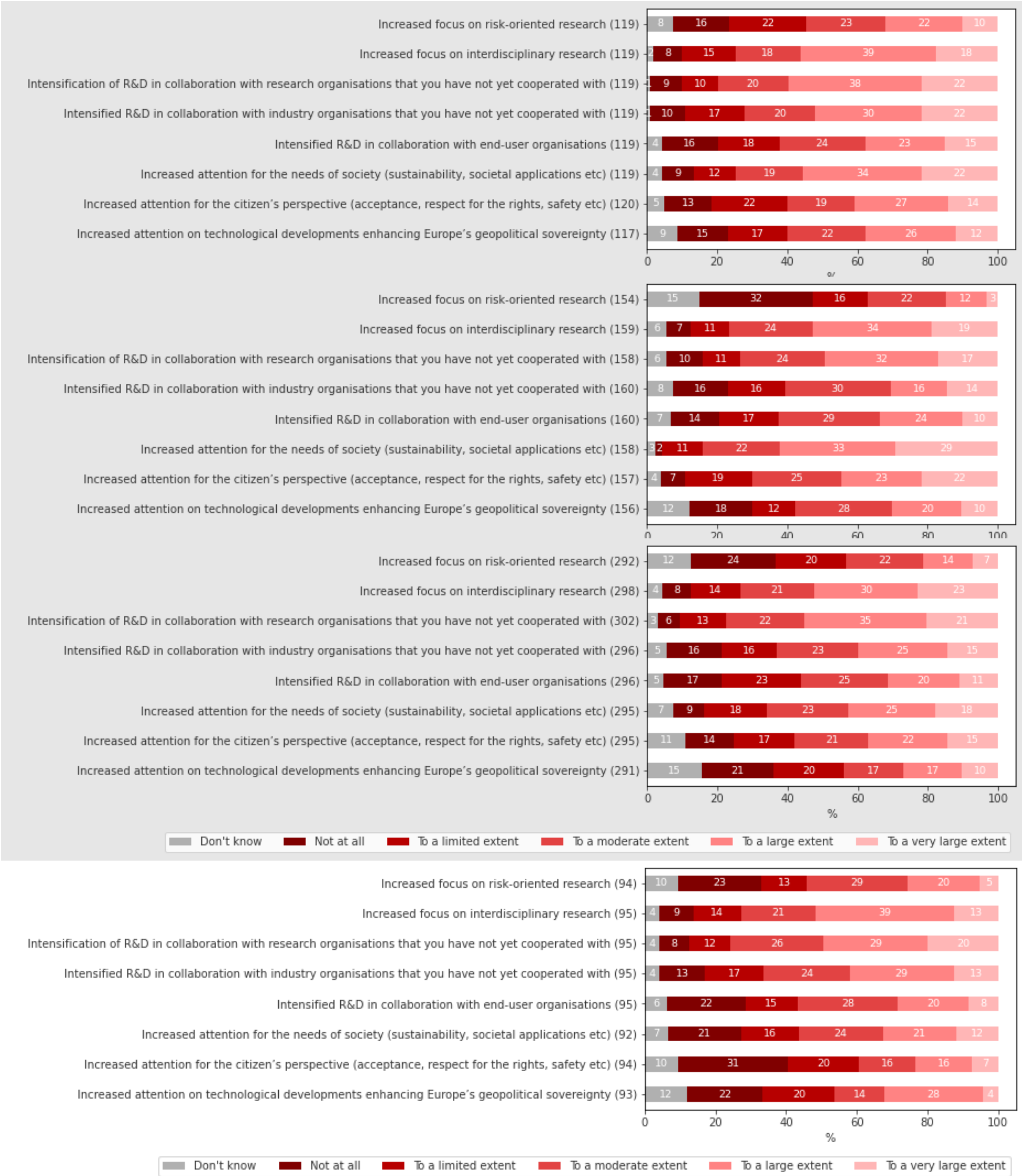


Figure 166 Q26 ‘To what extent did your project influence the following aspects of your organisation?’ per type of project: IA, CSA, RIA, and Art. 187 partnerships from high to low.

For all four project types 'Contribution to scientific and technological development' (52-66%) and 'Contribution to knowledge and capacity building' (59–75%) stand out as the aspects of expertise which have improved the most. Similarly, 'Contribution to market and business development is the expertise component which has been improved to the lowest extent for all four. However, with 20 -38 % of respondents considering it has been improved to a large or very large extent it remains a tangible contribution.

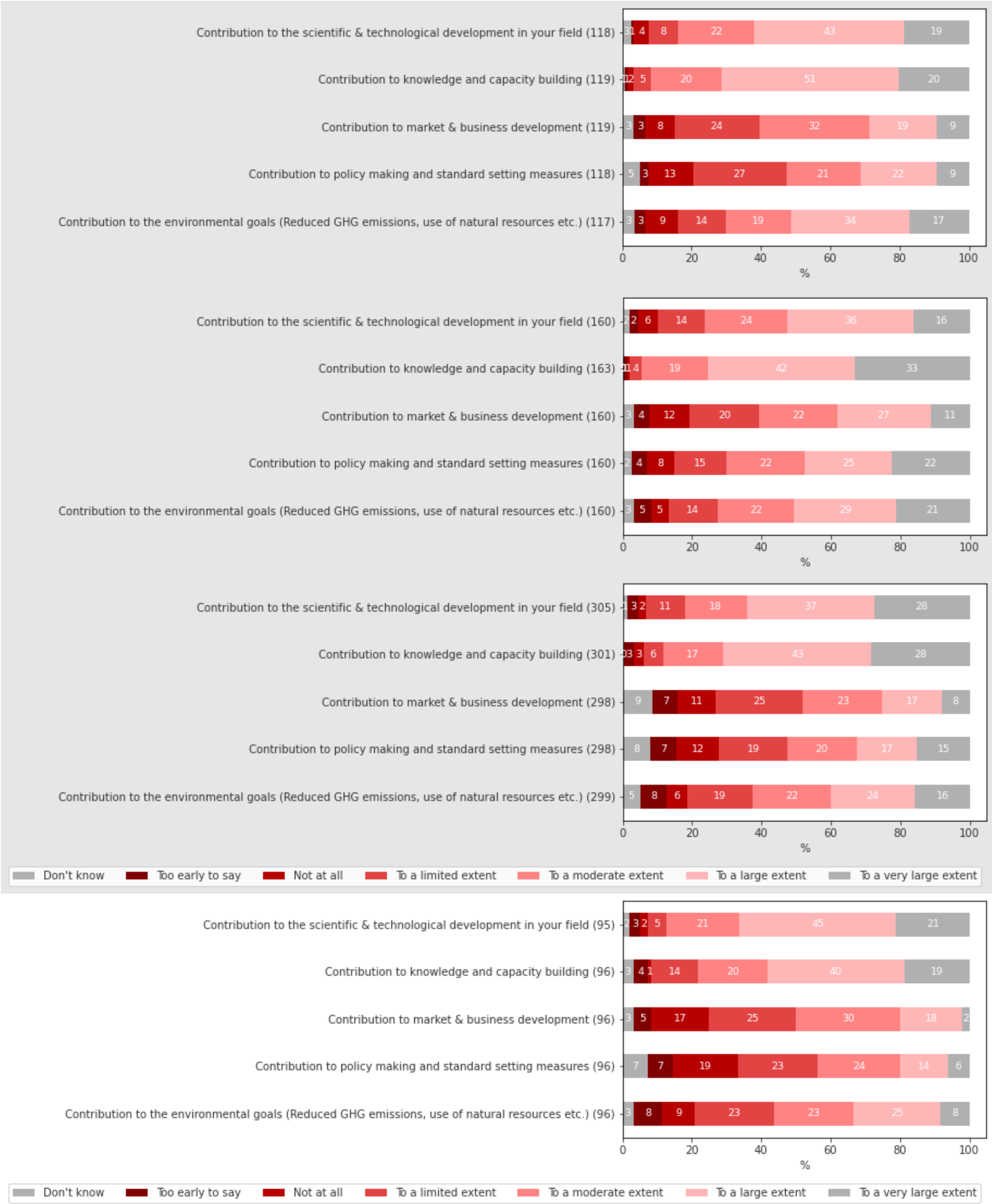


Figure 167 Q29: How successful was your project in terms of contributing to the following dimensions in your area of expertise?' per type of project: IA, CSA, RIA, and Art. 187 partnerships from high to low.

In terms of EU-added value, an overwhelming majority for all project types noted that the project would not have been implemented or would have been reduced in scope without H2020 support. However, respondents for IA, CSA and RIA projects consider with a significant majority that funding at a national or regional level could still have been found outside of H2020 (49-59%). For Art. 187 partnerships this was not the case (19%).

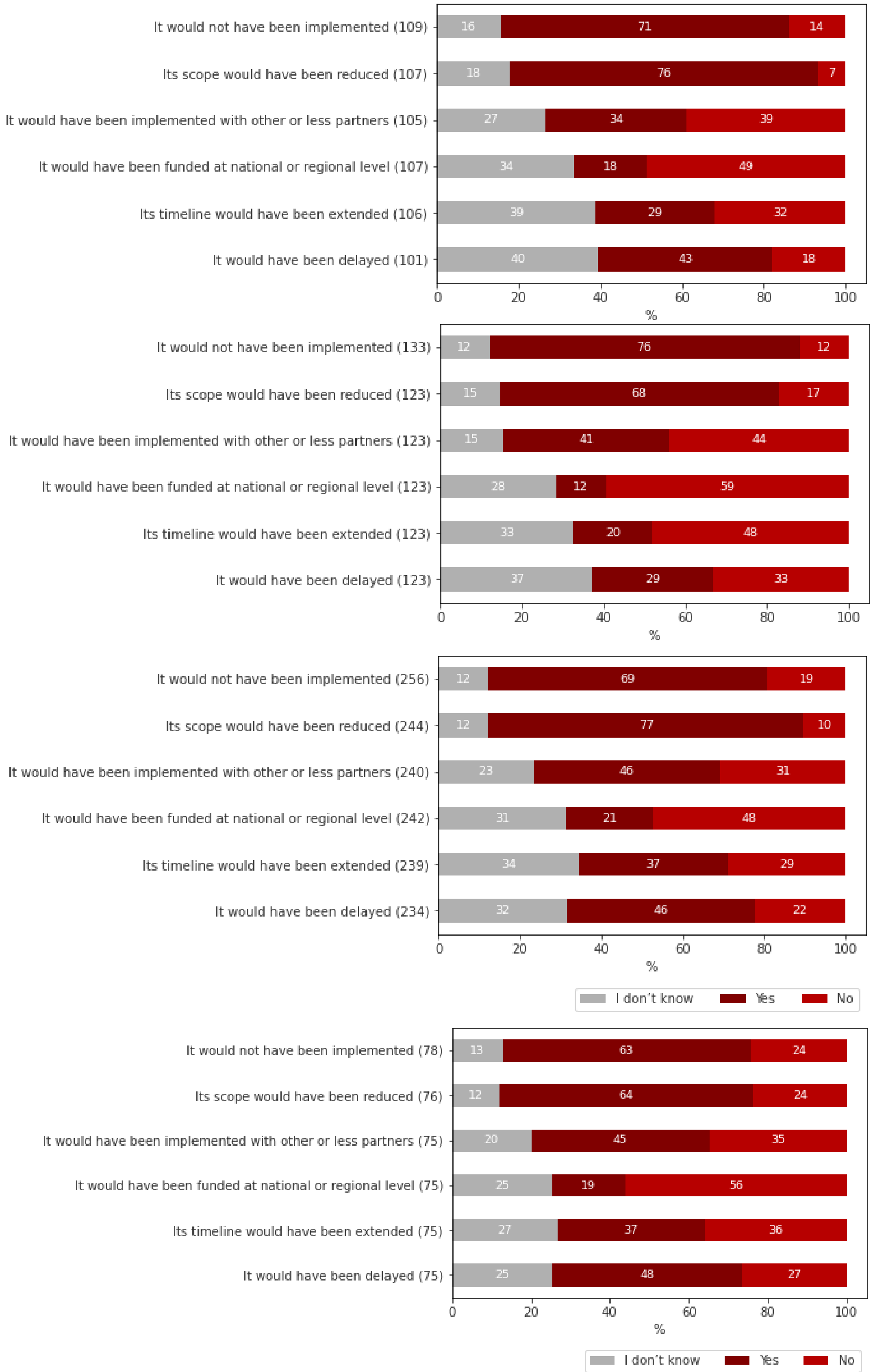


Figure 168 Q51 'Without support from H2020, what would have happened to your project?' per type of project: IA, CSA, RIA, and Art. 187 partnerships from high to low.

3. Efficiency of Programme Implementation

3.1. Administration and management

Some 75% of the respondents have been satisfied to a large or very large extent with the administration and management of the EC. 9% do not know or have been satisfied to a limited extent or not at all.

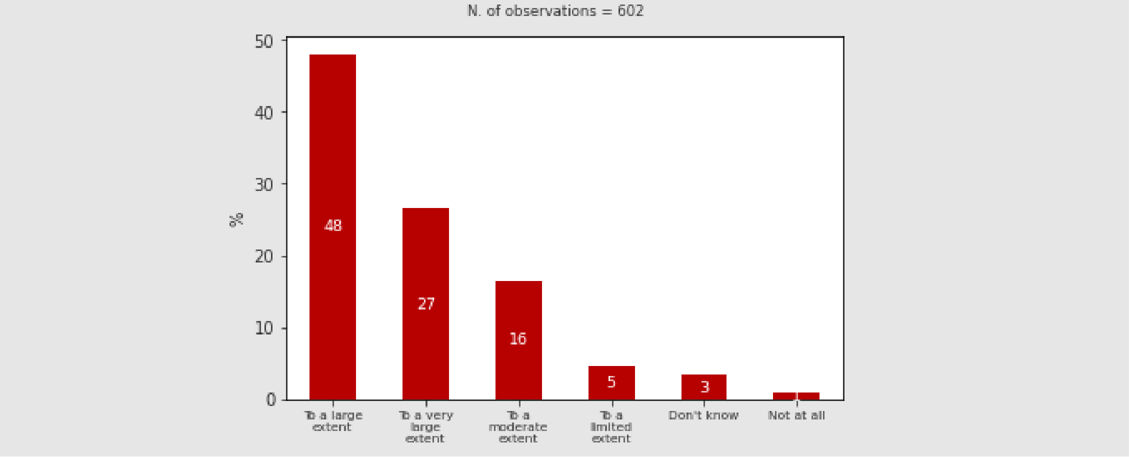


Figure 169 Q60: How satisfied are you with the administration and management of the EC during the runtime of your project?

Q61: Do you have any suggestions to improve the administration and management of the EC?

The list below is a summary of the suggestion provided by the survey respondents:

- There is a need for stability of the project officers and to ensure continuity in case of change. It would be advisable to give the project officers more autonomy to decide and not just advise. The decision-making is too far up into the CINEA chain of command.
- More time for project officers to interact with project coordinators. They seem to have far too many projects to be able to properly understand the ones they are overseeing.
- Sustained communication with the scientific officer. This also allows a personal attitude of the Project Officer which is beneficial to the project. Reduce feedback time and communicate with all partners of the consortium. More direct online meetings (once a year) between WP leaders and EC would facilitate the administration tasks.
- More flexibility in cost allocation as many factors change in terms of personnel, resources and others from the initial submission to the project acceptance and closing.
- There is a need for further simplification, introducing lump sums and getting closer to a service contract logic. There should be fewer periodic reports.
- Progress reviews should be planned in such a way as to be useful for the final outcome.
- The application process and administrative requirements are so demanding that medium-sized research institutions cannot lead a project proposal. It is a problem that the system is so complicated that only the large ones can manage to succeed with proposals.
- There is a need to accelerate the refunding process. 6-9 months between the funding period and reception of funding is too long for small companies.
- There is a need for clearer communication about expectations on deliverable format from the start. Clear in advance structuring of administrative checkpoints.
- Easier, more intuitive web interface. A well-documented 'how-to?' section in the EC SyGMa portal is currently lacking and would be very beneficial to improve the efficiency of continuous and periodic project reporting. Video tutorials on the use of the platform would be of help.
- Increase the understanding within the Commission that SMEs are not academic institutions nor do they have the same resources, experience, or objectives.
- More attention should be given to the integration and coherence of the different work packages. This would require additional monitoring and reviewing time and capacity (larger and more multidisciplinary review/monitoring team).

- The monitoring should follow a logic of checking the process rather than checking deliverables. The evaluation of project implementation focuses on purely administrative aspects and little attention is paid to the technical development achieved.
- There is a perception among some respondents about too much bureaucracy e.g. concerning contract amendments. There is a need to decrease amendment decision time and simplify the rules over budget transfers.
- The rigidity of administration should be reduced, especially for complex projects with strong external influences, partnerships and co-funding.
- Internalise most of the 'measures to maximise impact' (e.g., workshops, websites, social media presence) to avoid duplication of efforts and R&I funding going to social media managers rather than innovators. Collect lessons learnt (including about things that do not work) and open questions to inform future calls. Actively create links and share insights between funded projects.
- Simplification was a keyword when preparing FP8, also when preparing FP9, it is obvious that the administrative processes are perceived as heavy by a majority of contributors, the EC knows that and intends to change that. But after all EC services have contributed to establishing processes, obligations, forms etc. in a new program, they are at least as heavy as before and all participants in the program note this and complain again.
- On implementation, the EC should bring back the FP7 set-up with equality between Level 3 (JTI, EPCA) and collaborative research with Level 1 and Level 2 projects and therefore should interact with relevant stakeholder groups (not only certain big players) directly. The success rate especially for collaborative research applications must be significantly improved. The currently low rates are a real threat to the attractiveness of this instrument for industry.
- Projects are designed more than a year before their start, and successful projects wish to react to successes in ways that couldn't have been foreseen at the time of project design. Changes take too much effort/delay. This hurts the success of successful projects.
- Improve the funding and tenders portal (lots of technical issues), always very friendly exchanges with EC staff but often not up to date with the different project administrative requirements: improve training of EC project officers and advisors.

Between 61% and 72% of the respondents agree or strongly agree with the statement that contractual relationships with the Commission were user-friendly (61%), managed in a timely manner (72%) and proportionate to the time needed for complying with them (63%). Less than 10% of the respondents disagree or strongly disagree. A significantly high share of the respondents is neutral on the topic (24-30%) which speaks of certain reservations which are not too strong to voice.

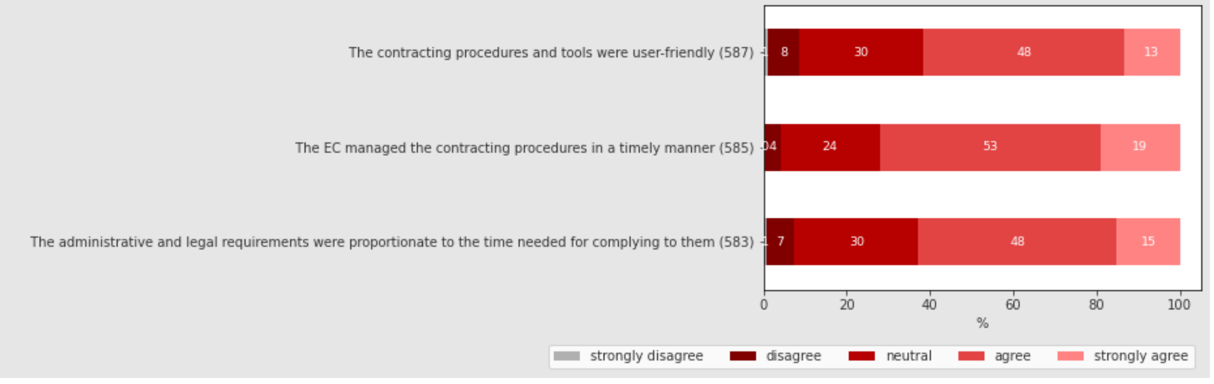


Figure 170 Q63: To what extent do you agree with the following statements related to the contractual conditions of the Horizon 2020 project? Contracting procedures and tools.

The respondents were rather positive (agree and strongly agree) with regard to the clarity of the funding scheme (82%) and the adequacy of the funding schemes for the organisation of the respondent (76%). Between 3% and 7% of the respondents disagree or strongly disagree. Specifically for NGOs and SMEs, 65% and 79% were positive on the adequacy of the funding scheme, and 6% and 7% were negative, respectively.

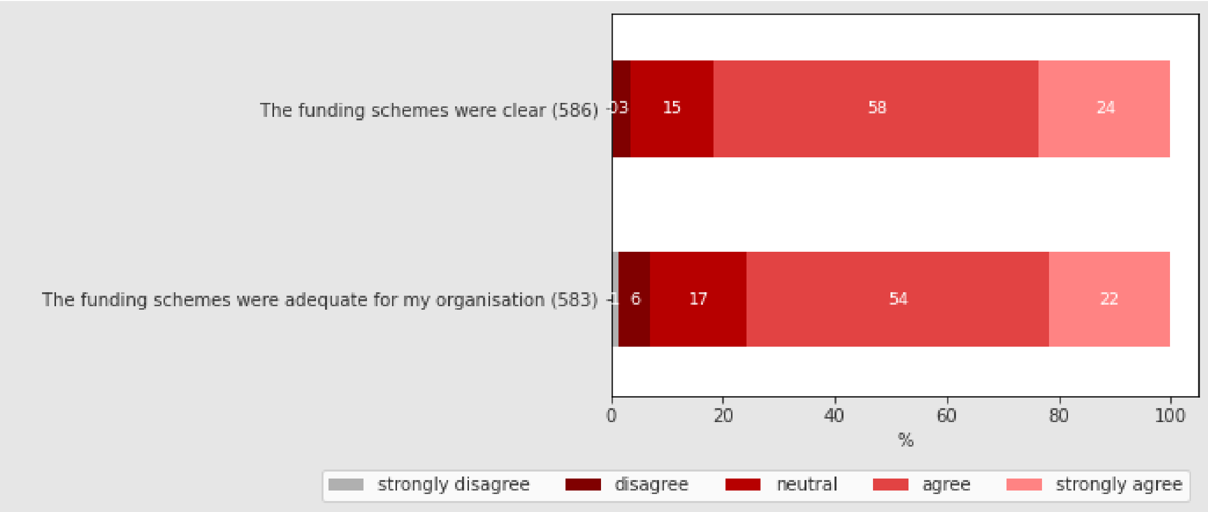


Figure 171 Q64: To what extent do you agree with the following statements related to the contractual conditions of the Horizon 2020 project? Contractual conditions of the funding schemes (overheads, fixed sum etc.).

In addition, respondents were overall positive towards different aspects of EC project management and monitoring: between 58% and 72% agree or strongly agree. The lowest support goes to the user-friendliness of the reporting platform (58%) and the usefulness of technical support (60%).

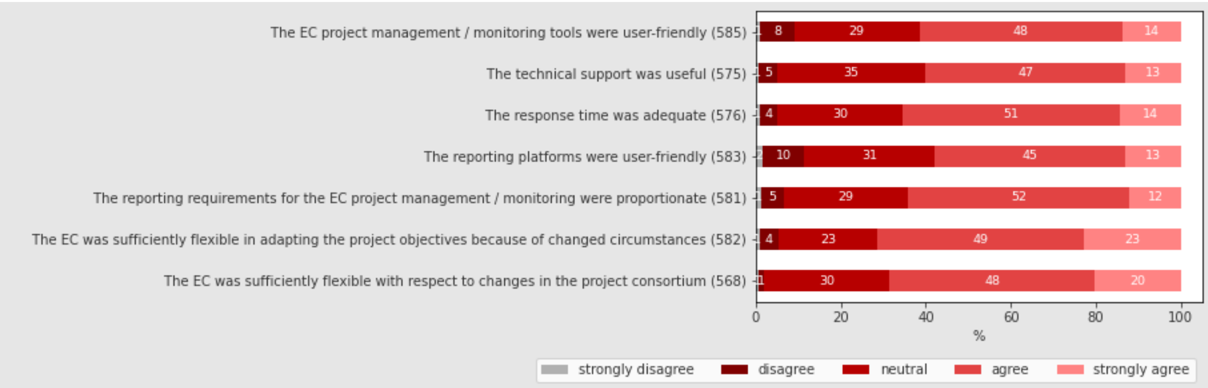


Figure 172 Q65: To what extent do you agree with the following statements related to the contractual conditions of the Horizon 2020 project? EC project management & monitoring.

Overall, the respondents were positive towards the adequacy of funding conditions for achieving the expected project results monitoring and between 52% and 56% agree or strongly agree that the project funding was adequate (52%), the size of the project consortium was adequate (56%) and that the project duration was sufficient (55%).

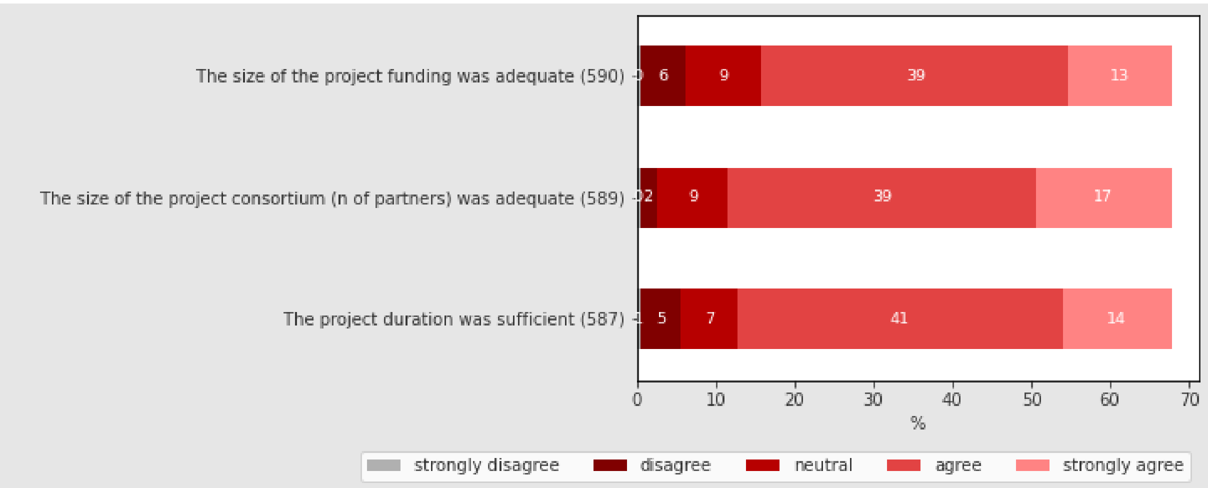


Figure 173 Q66: To what extent do you agree with the following statements related to the contractual conditions of the Horizon 2020 project? Adequacy of funding conditions for achieving the expected project results monitoring.

3.2. Project application and selection processes

Some 73% of the respondents have been satisfied to a large or very large extent with the application process. Only 8% do not know or have been satisfied to a limited extent or not at all.

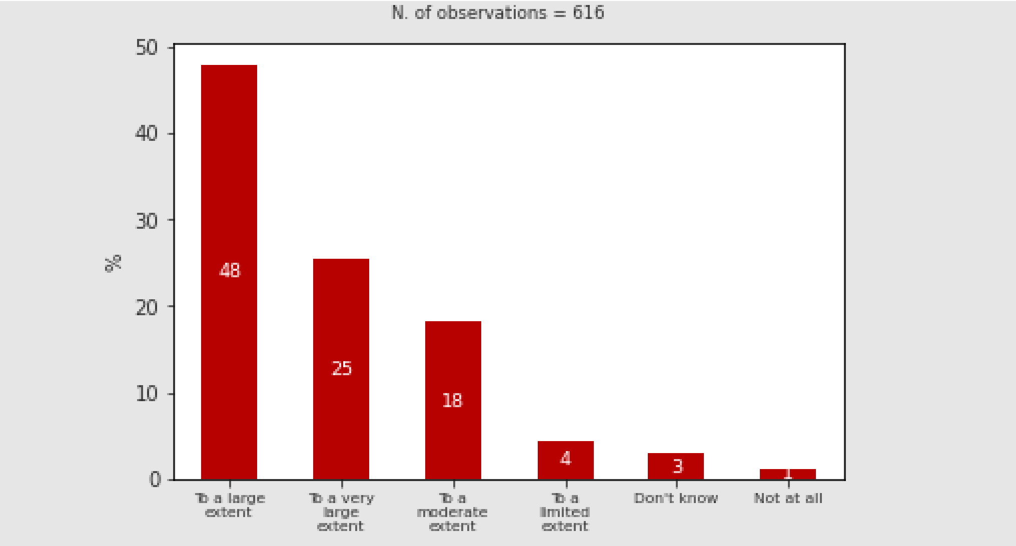


Figure 174 Q52: How satisfied are you with the Horizon 2020 application process for your project?

Between 47% and 70% of the respondents believe that different aspects of the application process were satisfactory to a large or very large extent. The satisfaction is the highest with regards to 'Clarity of aims and objectives of the calls' (70%) followed by 'Quality of EC communication activities' (68%). Respondents' satisfaction was the lowest concerning the 'Proportionality of the information required in the administrative proposal' and the 'User-friendliness of the proposal template' (47%).

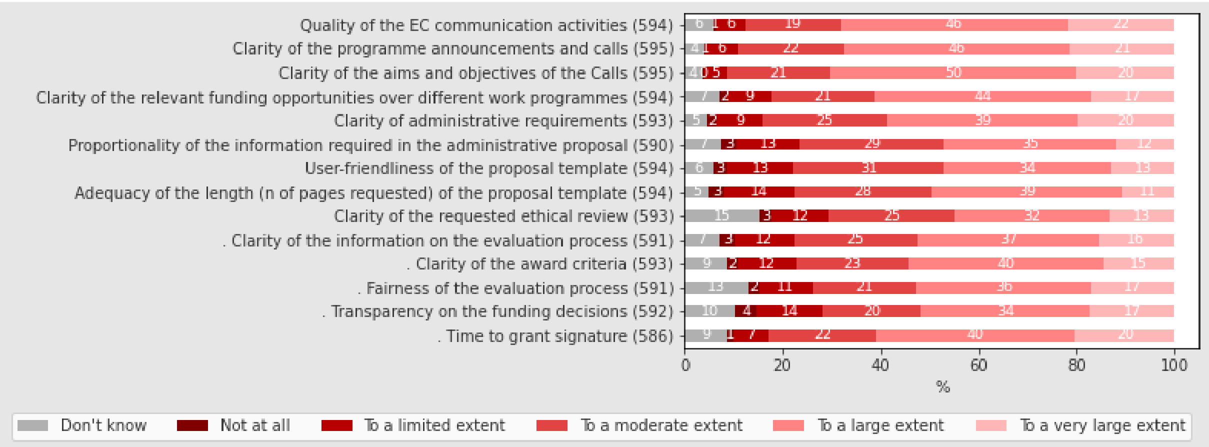


Figure 175 Q53: Based on your experience of applying to H2020 funding under the SC2, to what extent were the following aspects satisfactory?

More than one-third of the respondents estimated that the proposal required more than 30 person days from the organisation. Some 24% of the respondents evaluated it at 15-20 days and some 21% at 20-30 days. Only 17% of the respondents evaluated the efforts to be less than 15 person days.

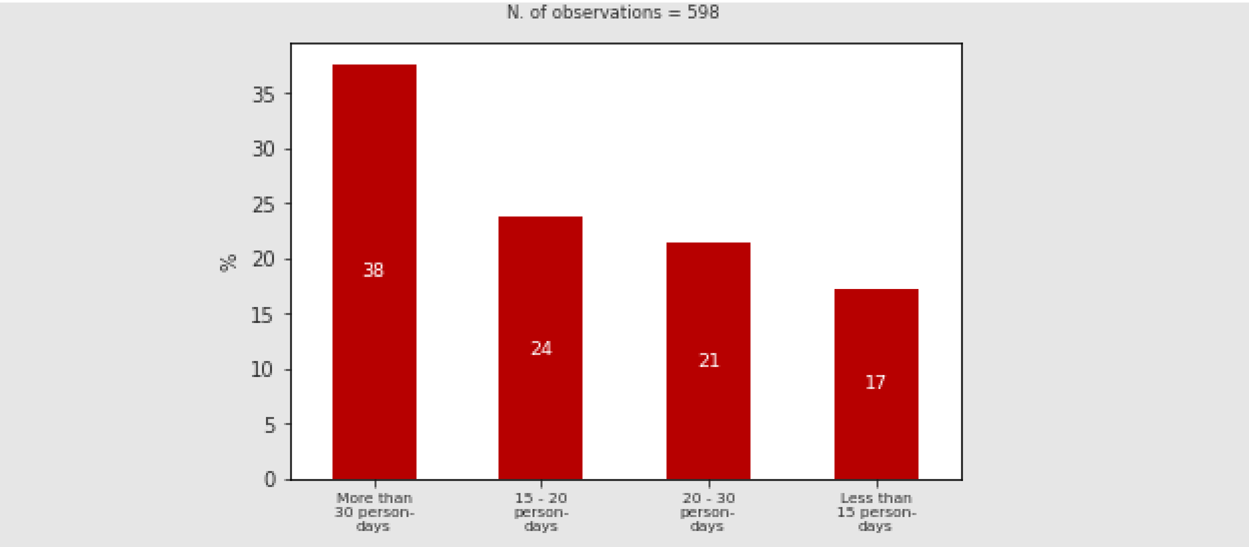


Figure 176 Q54: How much effort did the proposal require from your organisation in terms of person-days?

The big majority of respondents (59%) did not contact the National Contact Points. A bit less than one-quarter of the respondents benefitted from the NCP support while 17% have contacted the NCP without receiving the expected support.

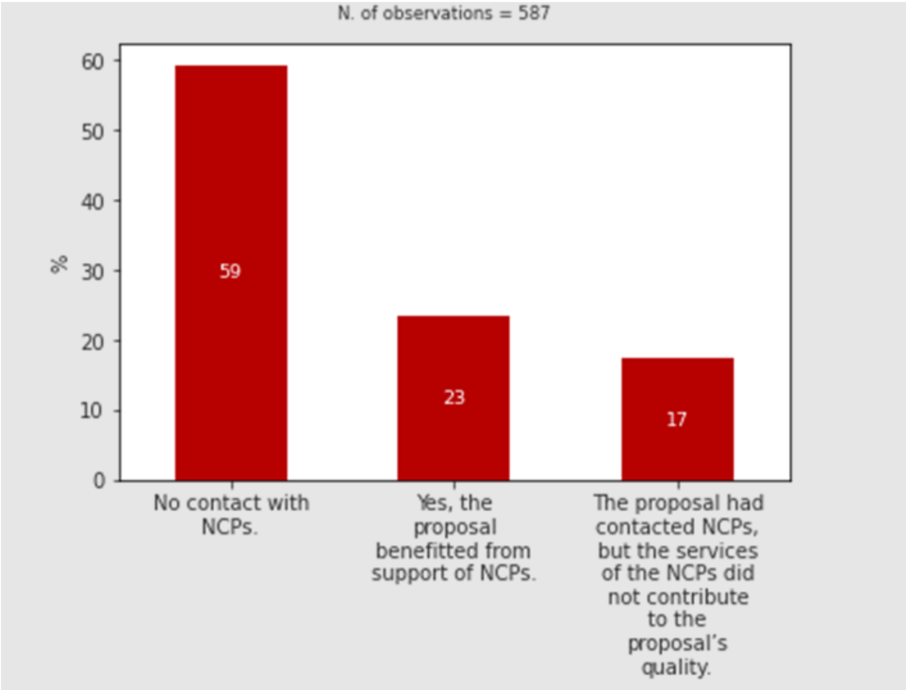


Figure 177 Q55: Did your project benefit from services of National Contact Points (NCPs)?

Between 60% and 88% of the respondents agree or strongly agree that the efforts were adequate with regard to all aspects associated with the preparation and submission of the proposal. The rate is the lowest with regards to the probability for a successful application (60%) while the four remaining aspects: volume of funding requested (73%), the complexity of the proposed projects (77%), the number of partners involved (78%) and the strategic relevance/interest in the research (78%), all of them being between 70% and 80% mark.

Only between 5% and 8% disagree or strongly disagree that the efforts are not adequate regarding all concerned aspects.

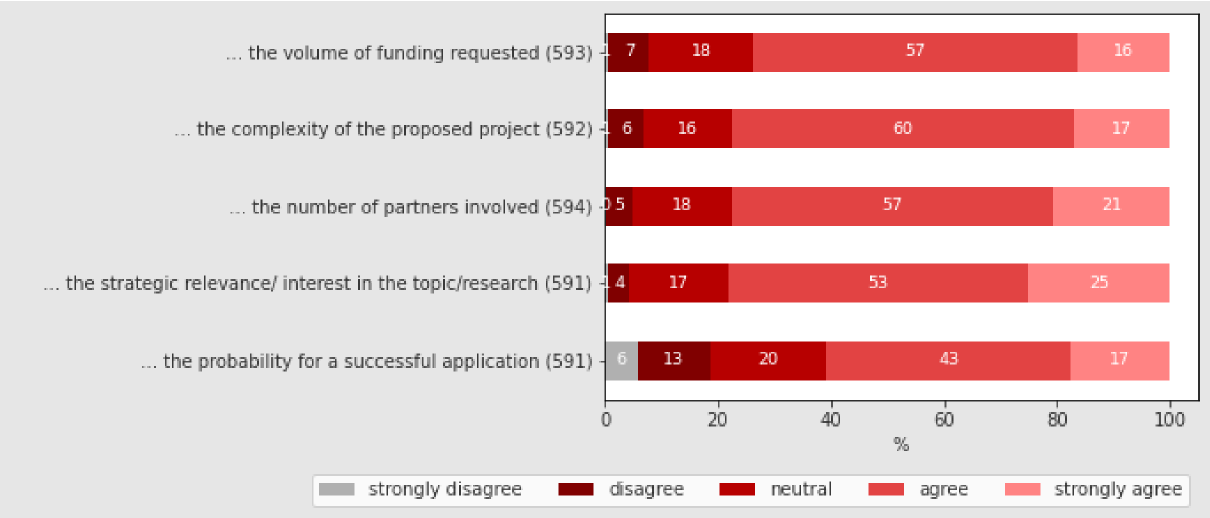


Figure 178 Q56: To what extent do you agree or disagree with the following statements in relation to the efforts needed for a proposal submission?

Two-thirds of the respondents (66%) went through a one-stage proposal and one-third (34%) – through a two-stage proposal.

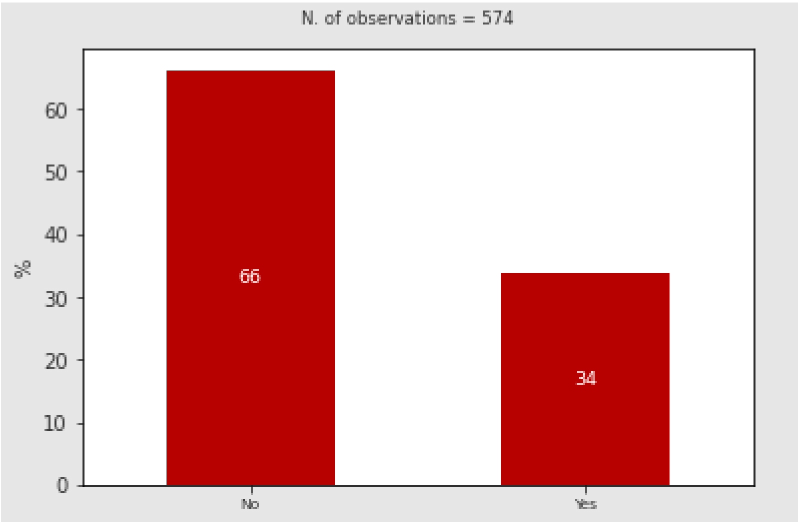


Figure 179 Q57: Was your project based upon a two-stage proposal process?

Almost half of the respondents (48%) think that the two-stage procedure substantially improved the efficiency of the proposal process. These respondents constituted of 33% HES and PRC, 19% REC, 9% PUB, and 8% Other.

Some 26% either don't know or believe that the two-stage procedure improved the efficiency of the procedure not at all (6%) or to a limited extent (13%).

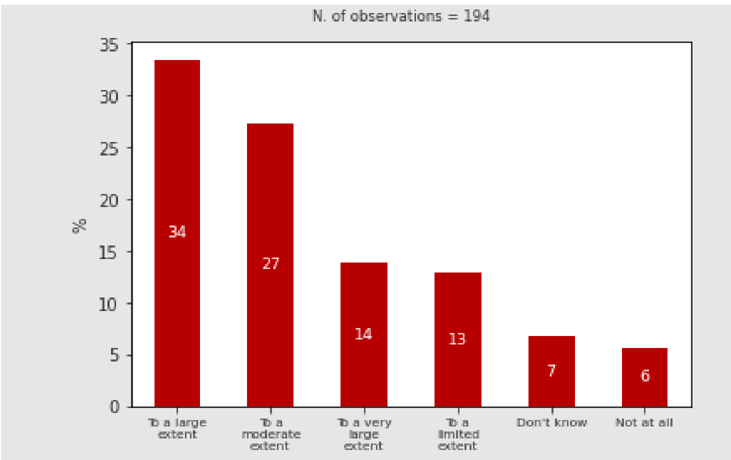


Figure 180 Q58: To what extent did the two-stage proposal process substantially improve the efficiency of the proposal process for your organisation?

Q59: Do you have suggestions to improve the selection process?

The following is a processed and grouped list of suggestions from the respondents:

- More two-stage calls would help to reduce the huge effort needed to write a good, multi-partners proposal. In the case of two-stage calls, less info should be required in 1st stage.
- There should be more focus on the actual work plan in the proposal instead of the conceptual text provided on excellence and impact.
- There is a suggestion to simplify the process and get support from the NCP for non-EU countries.
- For the largest projects, a final interview stage could be considered involving the project coordinator and work package leaders.
- Overall, there is an agreement that more transparency is needed in the evaluation process. Criteria and their weighing should be communicated openly. More of the general public should be involved in the proposal evaluation and they should have their say if this research is needed.
- There is a suggestion to speed up the selection process as technology evolves so fast at the time from the proposal to the approval is possible to have a private company that already started to develop the same or similar technology.
- Evaluators should be more experts in the topic of the proposals. Instruct reviewers in advance so that they have the same expectations from the call. Recently retired people or perhaps people from outside the EU should be involved. More reviewers per proposal to make the selection more transparent would also make sense.
- There is a suggestion to improve the consensus stage as high disagreements among evaluators are often evident and standardize remote hearings to explain the project if two projects are close in quality.
- There is a need for clearer and more specific criteria for the evaluation e.g. requirement for an advisory board.
- Reviewing needs to be consistent, fair and transparent and in the case of negative comments which contradict statements made in the application there needs to be a fair and rapid system for applicants to challenge the review.
- It could be better to have a permanent evaluation body that can assess proposals and select the ones with the highest impacts and needs of ERA and EU. The body could act as 2-3 level commissions e.g. 1st level -technical evaluation – 2 high-level scientific evaluation (scientific impact) -3 high-level political evaluation or similar
- More consultation services during application would be desirable.
- The review process should respect the differences between RIA and IA regarding the required details on industrialisation, market and business models for a solution. At TRL 5-6 the exploitation and business strategies and available details and data significantly differ from TRL7-8. Often, reviewers criticize the lack of industrialisation capacity in the consortium at TRL levels below 6, which is not reasonable.
- Coordinators should have the ability to respond to the reviewers' remarks! Proposals are rejected due to misinterpretation.
- The non-transparent selection of proposals from the waiting list should be replaced by a transparent procedure. There should be a possibility for very high-ranked proposals to get funding, too.
- More clarity of the EC expectations from the calls, the call descriptions are too general and offer too little information about what EC would like to fund. While this could be seen as positive for the creativity of the projects that could be funded, could be also seen as a clear EC vision of what proposals/projects could contribute.
- Decrease the amount allocated per project and increase the proportion of projects accepted.
- The call texts for certain topics appear to be more and more comprehensive (basically requiring the consortia to address too many aspects for limited budgets). This repeatedly creates quite a lot of confusion about which parts have to be focused on and which parts can be possibly neglected or at least considered only partially. Some evaluations (from reviewers) do not show the same quality and diligence as put into the proposal preparation. Hence, there appears to be very little

correlation between the anticipated chance of success and the actual success of several proposals we were involved in. It leaves us with the feeling of a lottery. A two-stage process would be better in which limited (!) effort is put into the first stage and only those proposals selected for the second stage are then required to invest a lot of effort in writing up a comprehensive proposal.

- Provide funding separately for projects involving parties with an established reputation and parties without such a reputation. A share of the funding should be available for parties that are entering the field for the first time.
- Have the possibility to disagree with reviewers and provide arguments against shortcomings or presumed faults.

Some 47% of the respondents invested less than 10 person/days for the preparation and signature of the proposal while some 37% invested between 10-20 person/days and 15% invested more than 20 days.

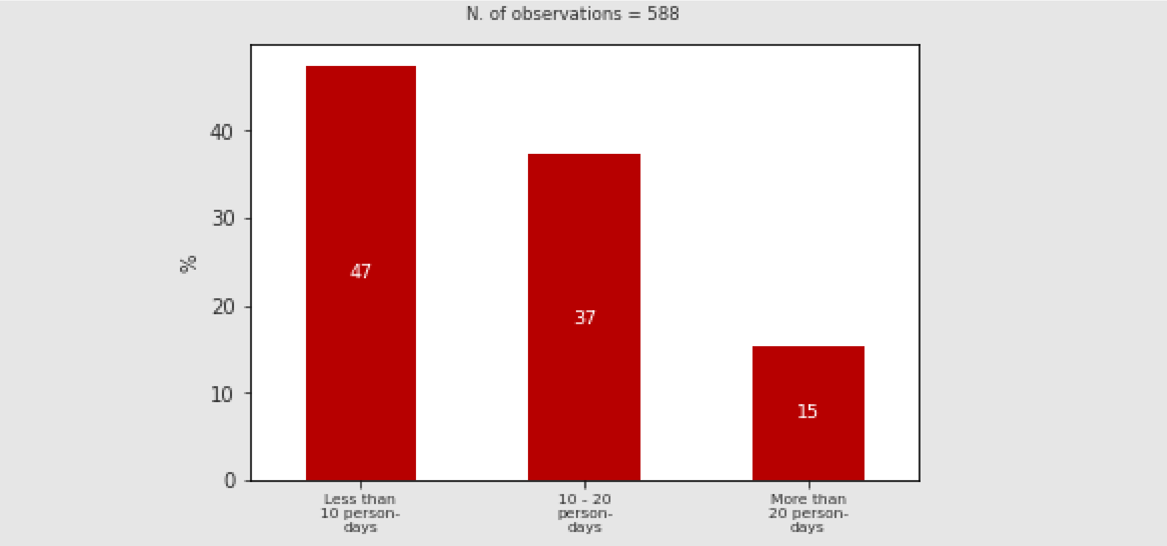


Figure 181 Q62: How much effort did your organisation need to invest in the grant preparation and signature?

3.3. Implementation

Almost three-quarters of the respondents answered that their projects were on time.

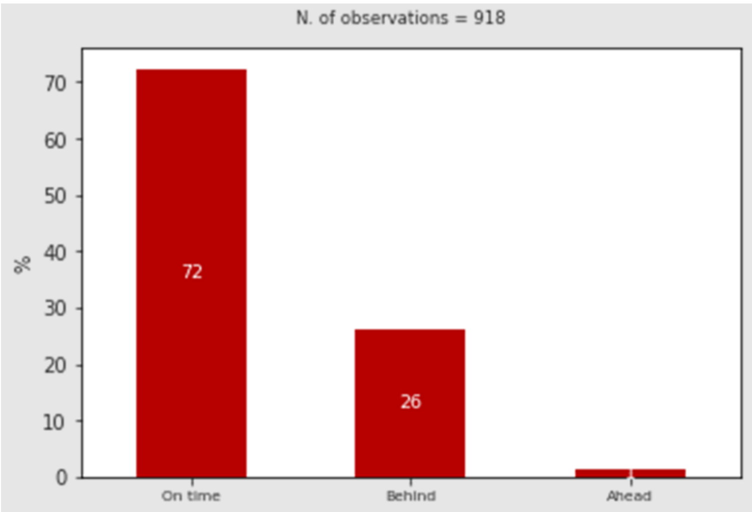


Figure 182 Q3: Compared to the initial schedule, is the project...

One-fifth of the projects (20%)did not require task redefinitions and almost half of the projects (46%) only required limited change. While around one-fourth of the projects (23%) required a moderate task redefinition, only 5% required task redefinition to a large or very large extent.

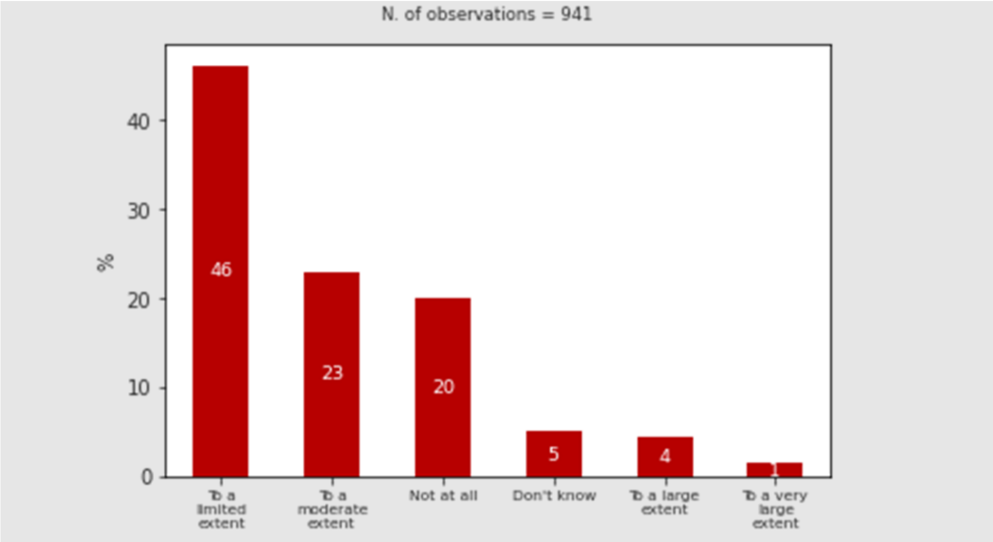


Figure 183 Q4: Did the project require any redefinition of tasks during the course of the project?

Respondents were positive about the degree of EC flexibility regarding the redefinition of project objectives (64% considered it to be the case to a large and very large extent) and changes in the project consortium (58%). Only 7% and 5% respectively experienced a lack of flexibility on behalf of the EC.

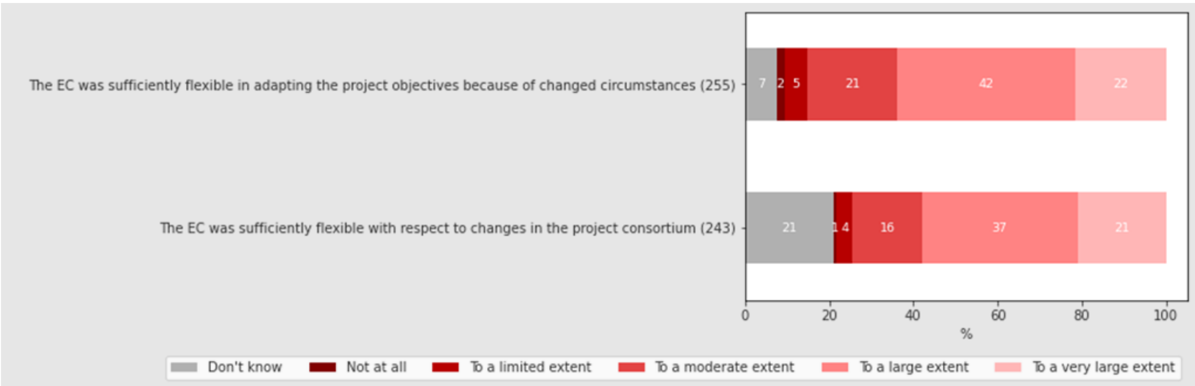


Figure 184 Q5: How flexible was the EC regarding the redefinition of tasks during the course of the project?

Half of the respondents participated in a FP7 project previously.

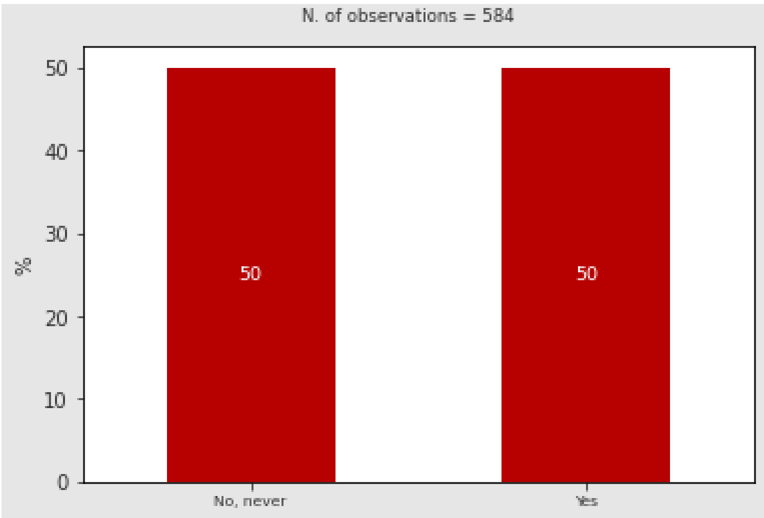


Figure 185 Q67 Have you ever participated in an FP7 project?

Some 54% of the respondents agree and strongly agree that proposal preparation and submission was simpler in H2020 compared to FP7. Some 9% disagree or strongly disagree.

Some 56% of the respondents agree and strongly agree that grant preparation was simpler in H2020 compared to FP7. Some 9% disagree or strongly disagree.

Some 60% of the respondents agree and strongly agree that the grant preparation IT tool was better in H2020 compared to FP7. Some 9% disagree or strongly disagree.

Some 57% of the respondents agree and strongly agree that the time to gran has substantially improved in H2020 compared to FP7. Some 1% disagree or strongly disagree.

Some 66% of the respondents agree and strongly agree that budget calculation and financial rules in H2020 are simpler compared to FP7. Some 4% disagree or strongly disagree.

Some 35% of the respondents agree and strongly agree that the no-negotiation approach made the project preparation more stressful and time-consuming in H2020 compared to FP7. Some 12% disagree or strongly disagree.

Some 31% of the respondents agree and strongly agree that the no-negotiation approach merely substituted the negotiation with early contract amendments. Some 8% disagree or strongly disagree.

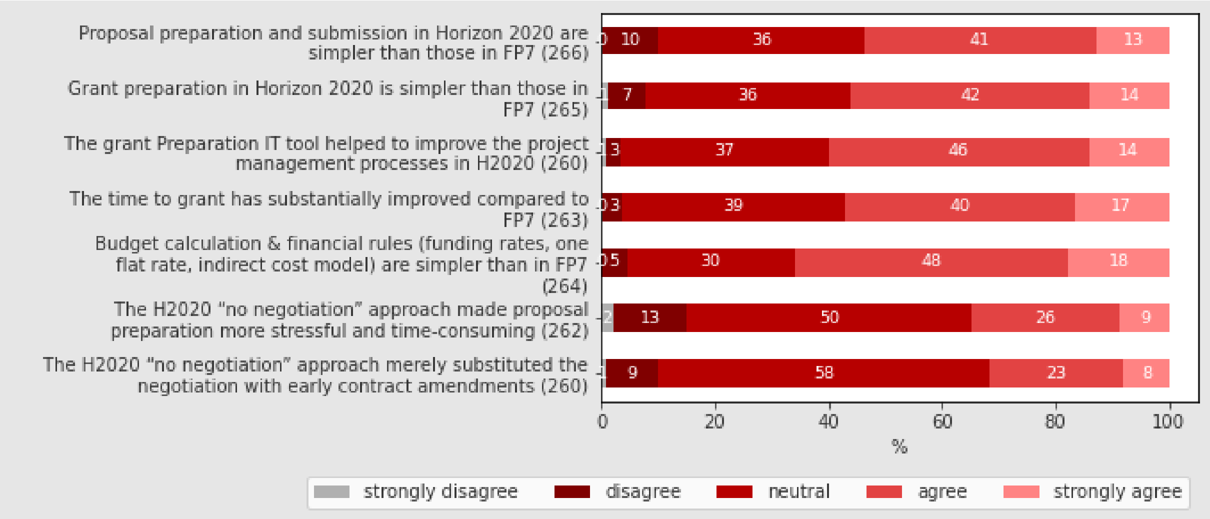


Figure 186 Q68: Based on your overall FP experience, to what extent do you agree with the following statements on the H2020 processes compared to FP7?

Some 38% agree to a large and very large extent that worktime recording should be further simplified. Some 35% don't know do not agree at all or agree to a very limited extent.

Some 35% agree to a large and very large extent that personnel cost calculation rules should be further simplified. Some 37% don't know do not agree at all or agree to a very limited extent.

Some 26% agree to a large and very large extent that rules of reimbursement on internally invoiced goods should be further simplified. Some 47% don't know do not agree at all or agree to a very limited extent.

Some 25% agree to a large and very large extent that reimbursement of indirect costs should be further simplified. Some 56% don't know do not agree at all or agree to a very limited extent.

Some 17% agree to a large and very large extent that ex-ante financial viability checks should be further simplified. Some 65% don't know do not agree at all or agree to a very limited extent.

Some 13% agree to a large and very large extent that the process establishing that an organisation is an SME should be further simplified. Some 66% don't know do not agree at all or agree to a very limited extent.

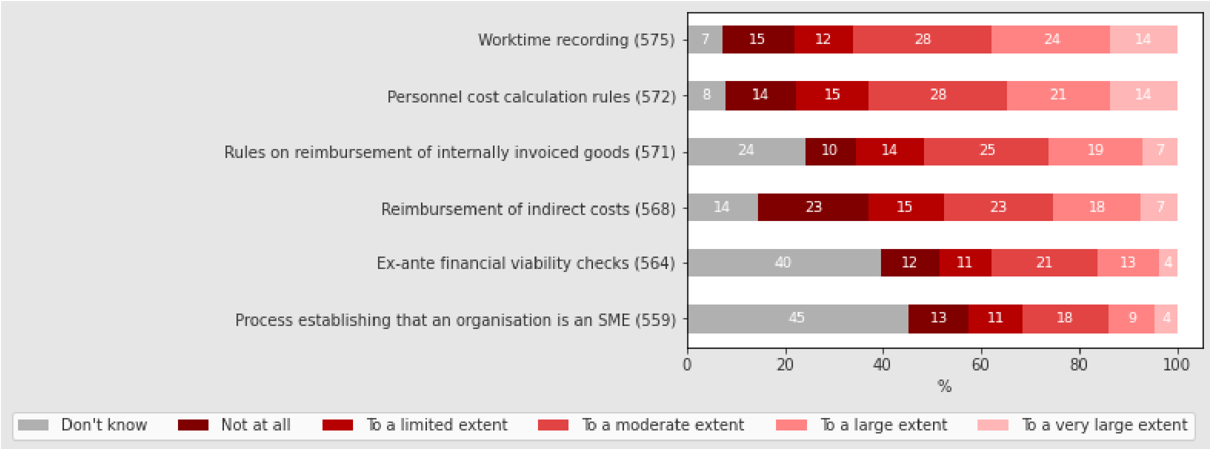


Figure 200. Q69: Following your participation to H2020, to what extent should the EC further simplify its administrative and financial requirements for the following aspects:

More than half of the respondents (53%) are participating in a Horizon Europe project.

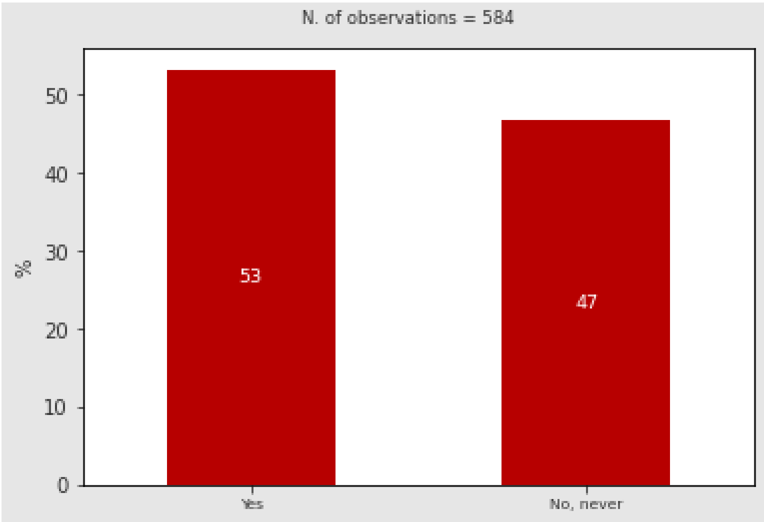


Figure 201. Q70: Are you participating to a Horizon Europe project?

24% of the respondents consider that within Horizon Europe the administrative and financial requirements have been improved to a large (18%) and very large extent (6%). Almost one-fourth (23%) think the improvement has been moderate while 22% consider the situation has improved to a limited extent (15%).

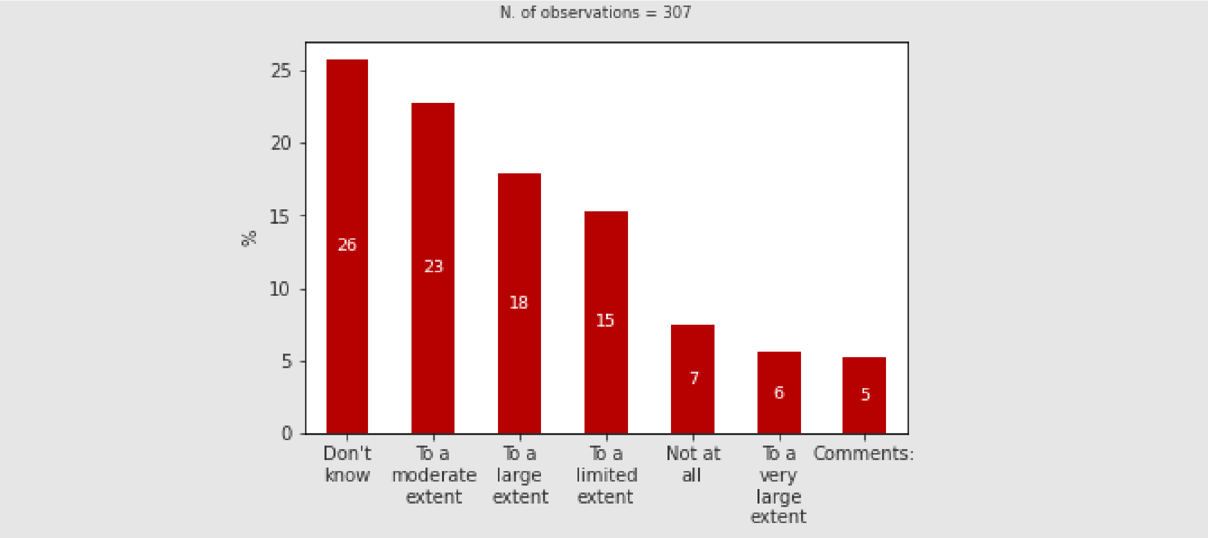


Figure 187 Q71: If you are participating to Horizon Europe, to which extent do you consider that the situation of EU administrative and financial requirements has already improved under Horizon Europe compared to H2020?

More than half of the respondents (53%) answered that the project coordinator was in charge of the administrative, financial and legal aspects of the project. Moreover, 19% pointed out that a special project management office within the project coordinator was in charge.

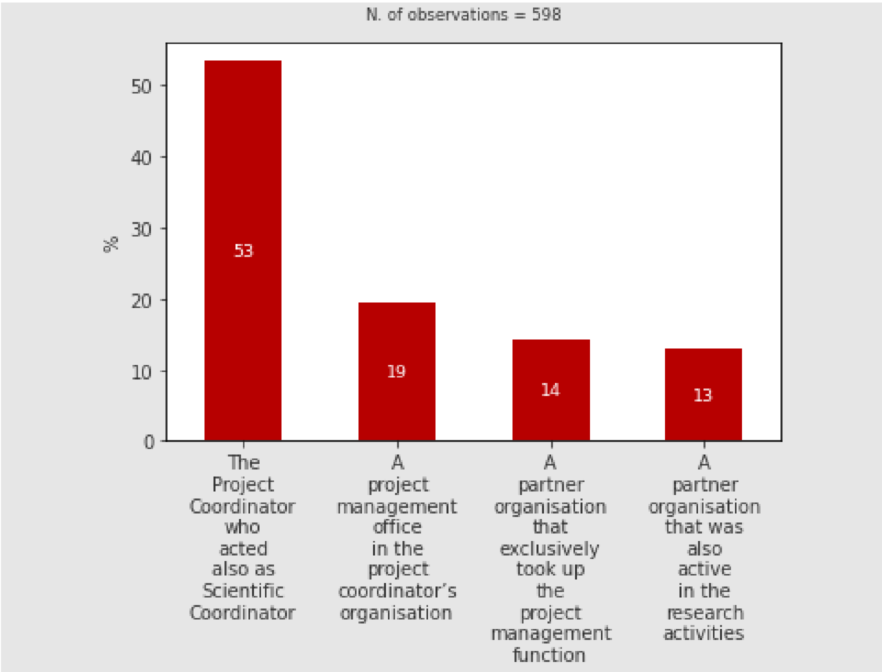


Figure 188 Q72: Who was responsible for the administrative, financial and legal aspects at the project level in your H2020 project?

There were two main reasons for choosing a project management organisation and these are: the increasing size and complexity of the projects (72% think this to be the case to a large and very large extent); and the improved efficiency of dealing with the administrative and financial issues (73%). These two drivers are followed by reduced management risk (54% to a large and very large extent). The lack of knowledge within the project coordinator was less of a motivation (38%).

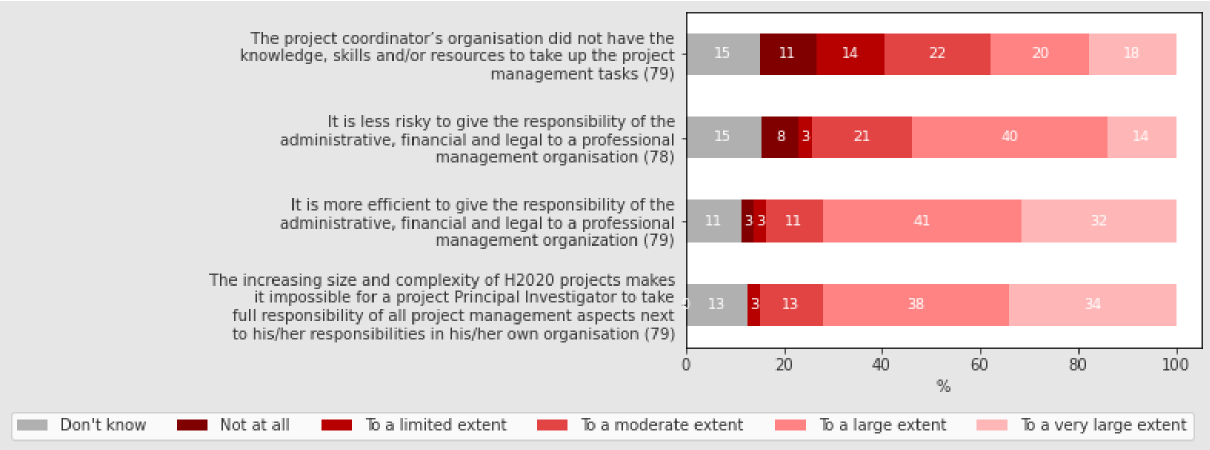


Figure 189 Q73: What have been the reasons for choosing a project management organisation?

Overall, around half of the respondents agree or strongly agree that the separation of project management and scientific coordination is positive. 53% agree or strongly agree it was beneficial for the project results to a large or very large extent. 60% agree or strongly agree that it allowed the principal investigator to spend more time on the quality of research activities and to dedicate more time to communicate with end users (53%).

Only 17% agree or strongly agree that the separation created confusion in the overall project management.29% agree or strongly agree that the project management and scientific coordination should not be separated.

The share of respondents who responded neutrally for each of the statements is relatively high which means that they may not have a direct impression or opinion on the issue.

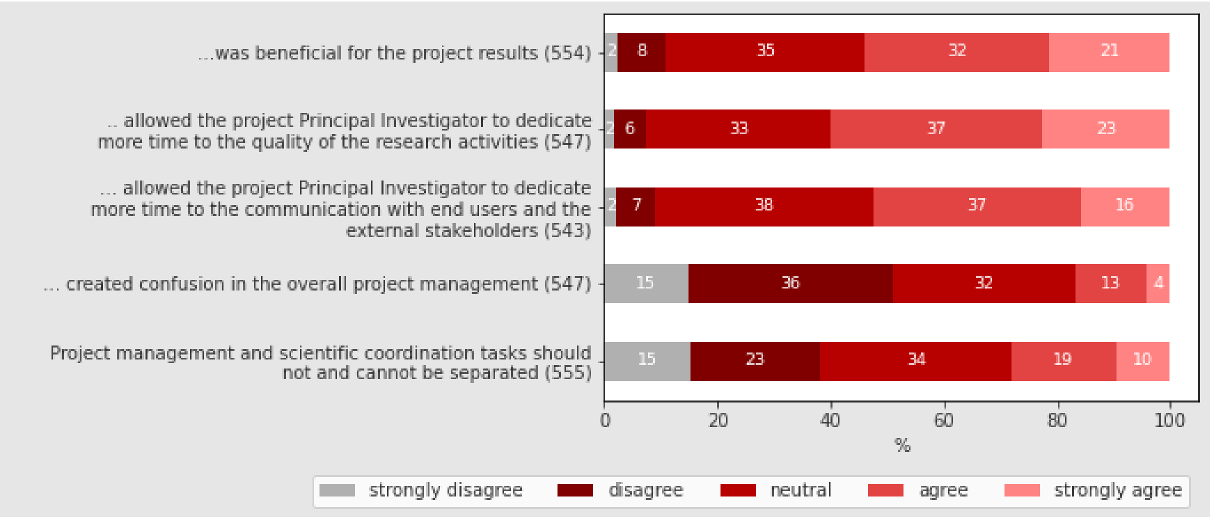


Figure 190 Q74: To what extent do you agree with the following statements regarding the separation of project management and scientific coordination?

Almost half of the respondents (42%) allocated no more than 25% of their time to administrative, financial and legal aspects while almost one-third (32%) allocated between 25% and 50%.

The ratios are inversed for time allocation to scientific, technical and innovation aspects. More than a third allocated between 75% and 100% of the time to it and another 35% allocated between 50% and 75%.

There are reasons for concern in around a quarter of the respondents who allocated far too much time for administration: 19% between 50% and 75% and 6% - between 75% and 100%. These same organisations had much less time to dedicate to scientific, technical and innovation aspects: 8% - 0-25% and 19% - between 25% and 50%.

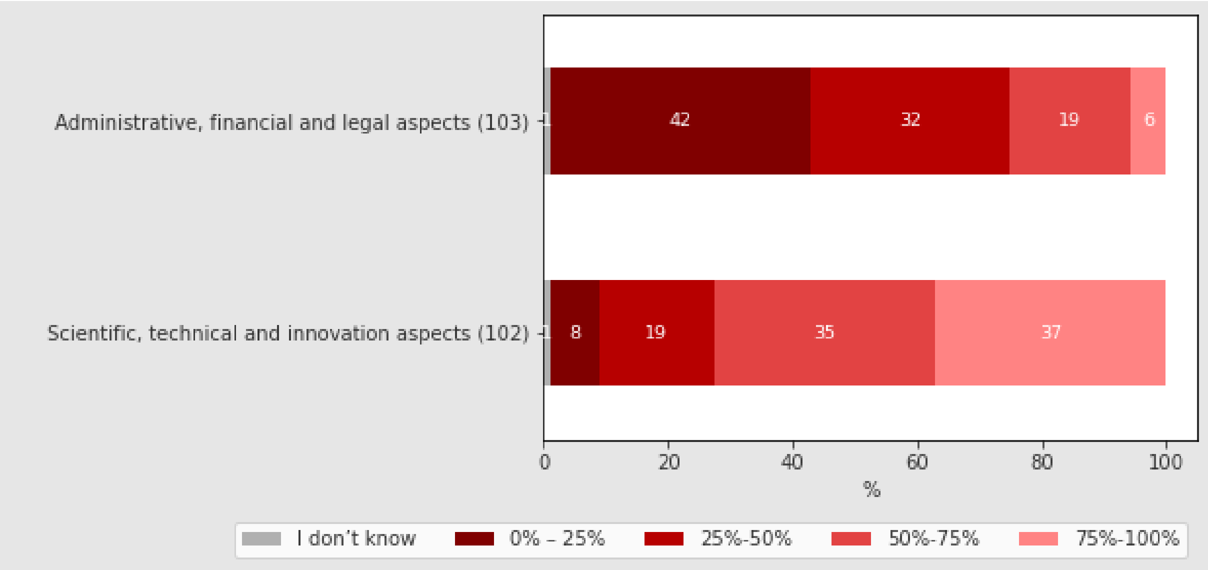


Figure 191 Q75: How did you allocate your time between these two categories of management tasks over the course of the project?

Expectedly, the tasks which rank the highest in terms of project management tasks are as follows:

- Coordinating the timing of deliverables and meeting milestones (55% assign it as first and second priority)
- Quality control of deliverables and project outputs (54%); and
- Communication inside the consortium (54%).

The three tasks which rank the lowest are:

- Monitoring of gender and other ethical aspects (3%)
- Dispute settlement (10%); and
- Preparation and conduct of review meetings (10%).

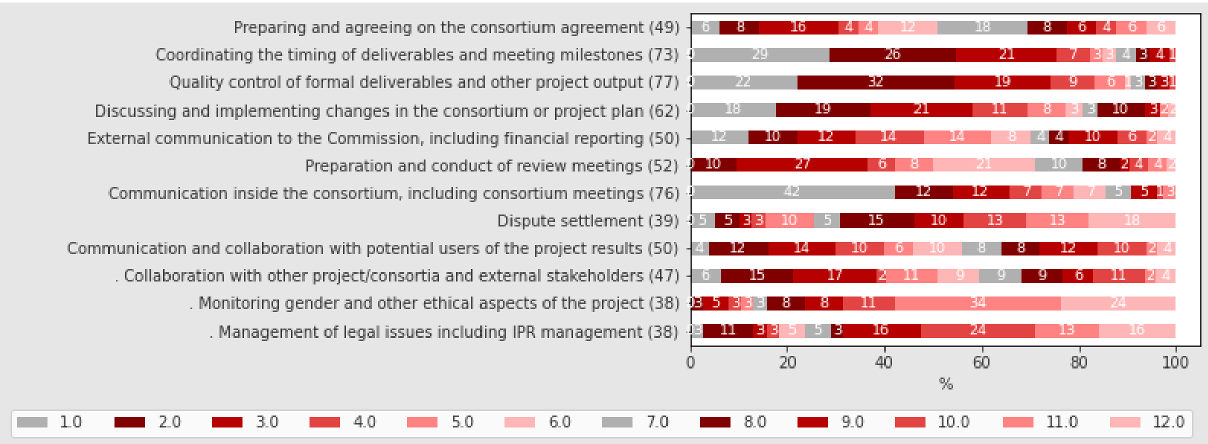


Figure 192 Q76: Please prioritise the top three project management tasks in order of the time you spent on them, 1 being most time consuming.

More than half of the respondents (54%) agree to a large and very large extent that coordination that goes beyond administrative, financial and legal aspects is crucial for the project. An additional 23% agree to a moderate extent.

At the same time, more than half of the respondents (51%) agree to a moderate, large or very large extent that the role of the Project Coordinator as defined by the EDC does not cover all aspects necessary for ensuring project success.

Around a third (29%) of surveyees think the actual time spent on management exceeded the budgeted costs.

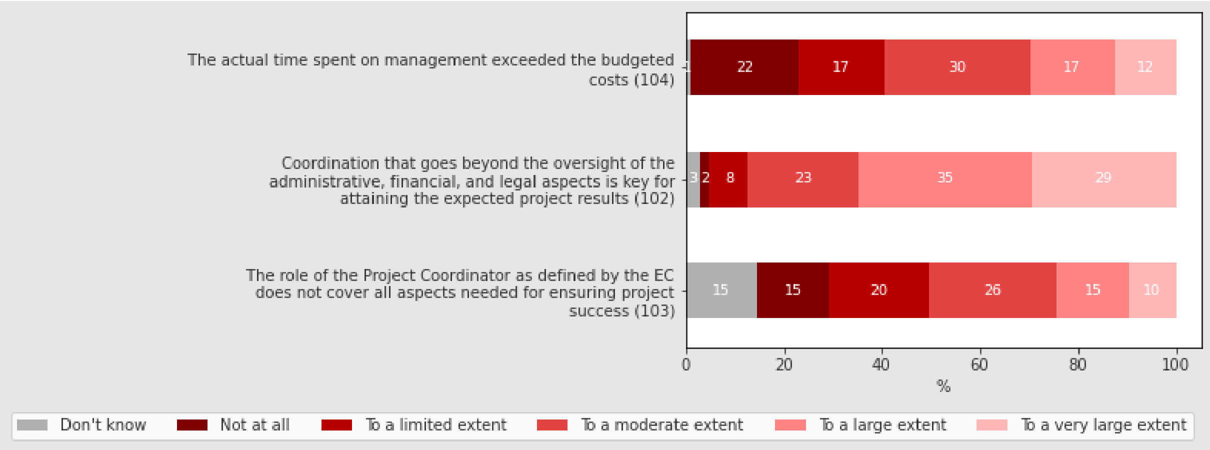


Figure 193 Q77: To what extent do you agree with the following statements related to your project management tasks?

4. Contribution to Green Transition

4.1. Building and Nurturing Niches

Between 64% and 78% of the respondents assess that the H2020 programme has responded somewhat sufficiently or completely sufficiently to their needs.

'Establishment of new fields of knowledge'' and 'Development of new ground-breaking solutions' stand out as the aspects to which the H2020 Programme has responded to the largest extent (somewhat and completely sufficient) (78% and 75%).

The aspects 'Protecting new fields of innovation from market influences' and 'Protecting new fields of innovation from dominant interests' have been responded to the lowest extent. Only 46% and 48% respectively think that they have been responded to somewhat or completely sufficiently.

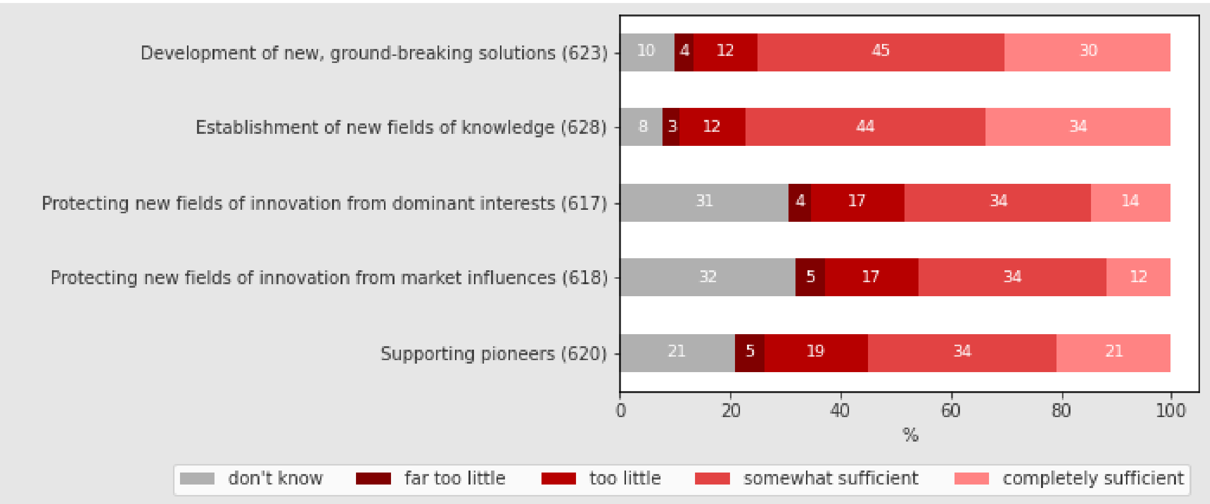


Figure 194 Q37: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Establishing and promoting new fields of innovation contributing to a green transition.

With regards to green transition Horizon 2020 contributed somewhat sufficiently and completely sufficiently for a large majority of respondents as long as four out of the five aspects of learning and exchange of experience below are concerned: learning about subject-specific problems (82%); exchange of experience on innovative solutions (83%); reflection on new solutions and their applications (79%); and slightly lower for promotion of professional competences (69%). Only the aspect of ‘Open communication of failures’ received 49% of positive answers (somewhat sufficient and completely sufficient).

For any of the mentioned aspects (except open communication of failures) the negative assessment did not exceed 17% of the respondents.

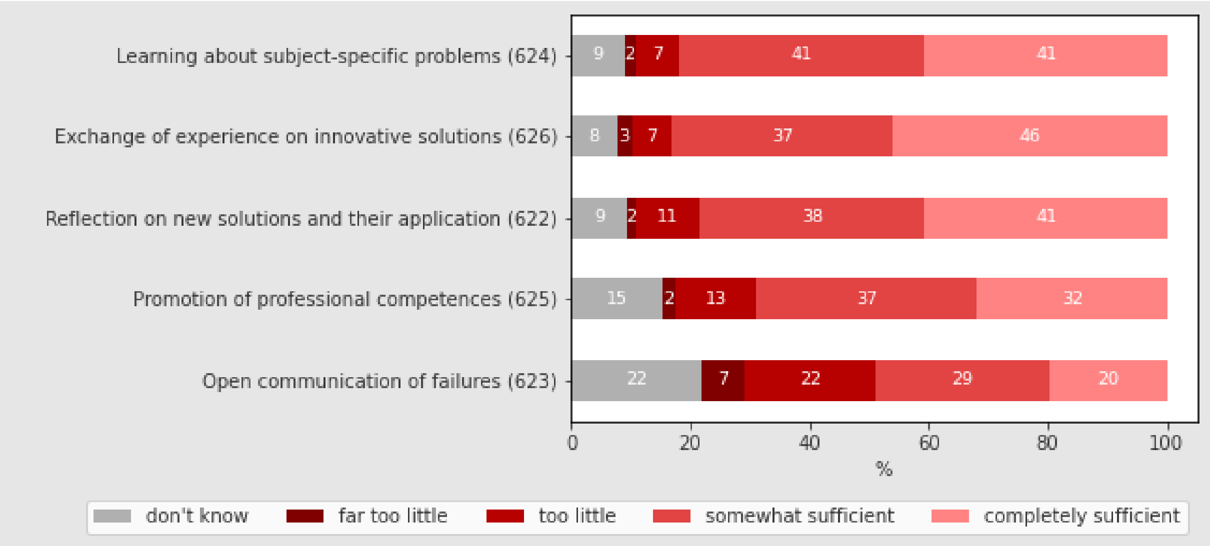


Figure 195 Q38: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Learning and exchange of experience in the field of green transition.

As far as promoting awareness of problems related to the green transition and new ways of solving them are concerned, around two-thirds of the respondents considered that H2020 responded somewhat or completely sufficiently to the needs of Green Transition for all aspects: Awareness of new ways of solving problems (68%); Questioning conventional ways of solving problems (65%); Critical questioning of established basic assumptions (61%). The aspect of 'Breaking down established ways of working' comes last with 57%.

It is interesting to note that a high share of the respondents don't know to what extent this has been the case. Around 20% of the respondents think that H2020 responded little or far too little to the different aspects.

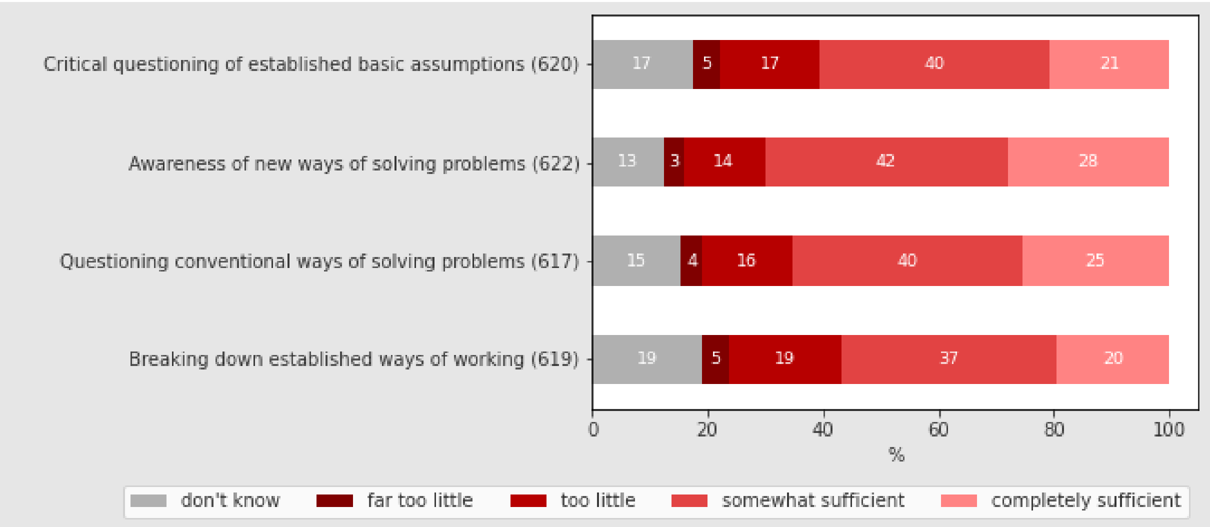


Figure 196 Q39: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Promoting awareness of problems related to the green transition and new ways of solving them.

With regards to networking between young innovation fields with Green Transition implications, around half of the respondents consider that H2020 projects respond somewhat or completely sufficiently to the different aspects. The network between new innovation actors comes first with 58% followed by networking between young innovation fields (53%); synergies between young innovation fields (51%) and lastly cooperation between pioneers (48%). Slightly more than 20% think the response to these needs is too little or far too little and more than one quarter do not have an opinion about that.

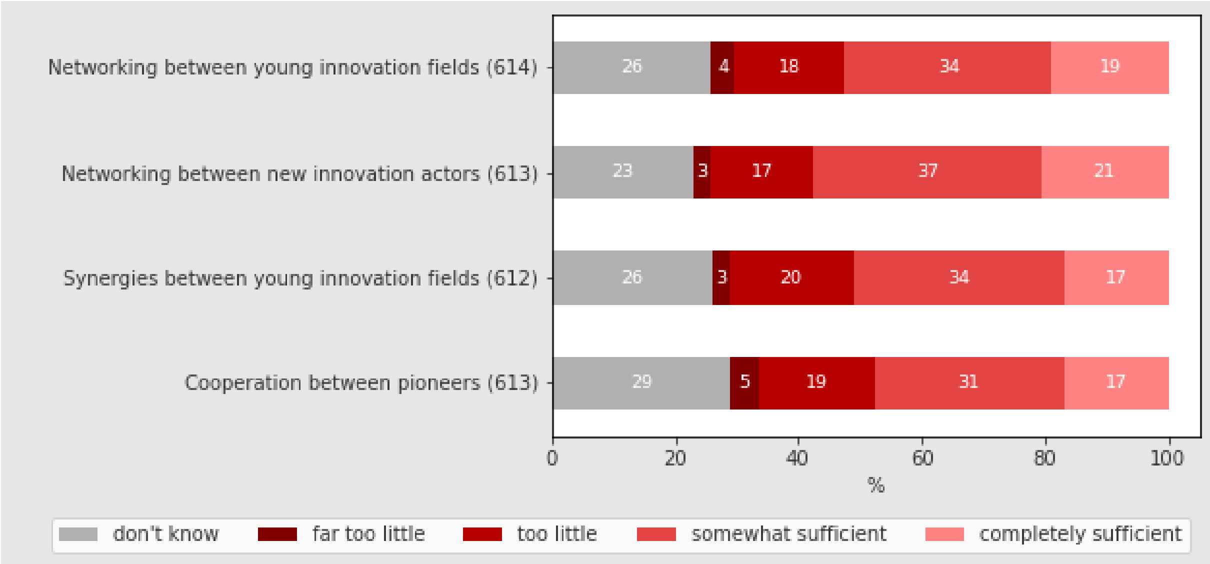


Figure 197 Q40: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Networking between young innovation fields with Green Transition implications.

With regards to Managing expectations with regards to the Green Transition and promoting shared visions, between 55% and 67% of the respondents consider that H2020 projects respond somewhat or completely sufficiently to the different aspects. A common understanding of the future directions of innovation fields comes first with 67% followed by strengthening innovative solutions as legitimate alternatives for the future(66%); the anticipation of future trends and shocks (57%) and lastly by reduced uncertainties about context conditions for innovations (55%). Slightly more than 20% think the response to these needs is too little or far too little and more than one quarter do not have an opinion about that.

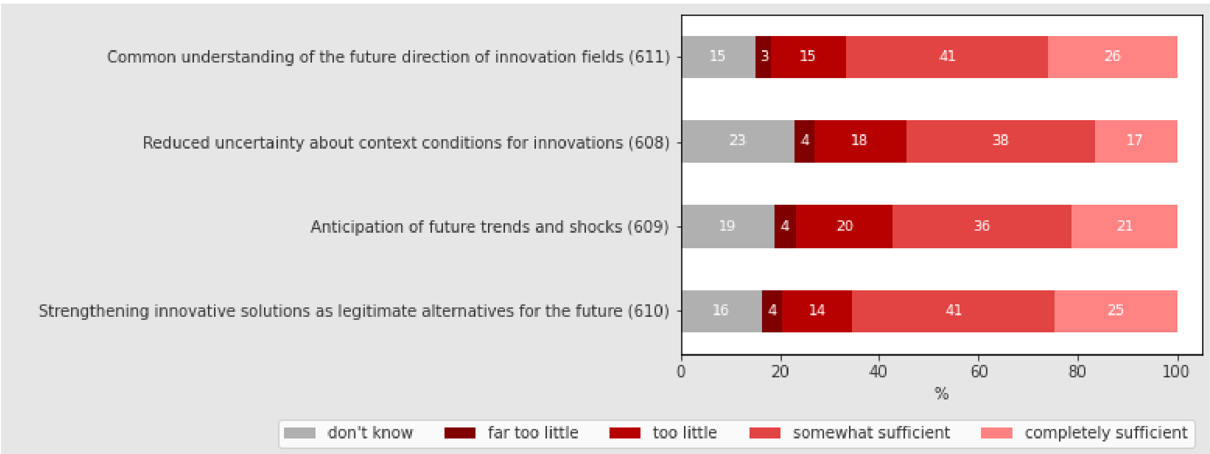


Figure 198 Q41: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Managing expectations with regards to the Green Transition and promoting shared visions.

4.2. Expanding and mainstreaming niches

With regards to the Expansion of new fields of innovation relevant to the Green Transition, between 52% and 60% of the respondents consider that H2020 projects respond somewhat or completely sufficiently to the different aspects. Broad acceptance of novel approaches comes first with 60% followed by large-scale use of innovations (57%); accelerated implementation of innovations (54%) and lastly by recognition of new 'rules of the game' associated with innovation (52%). Slightly more than 20% think the response to these needs is too little or far too little and between 15% and 20% do not have an opinion about that.

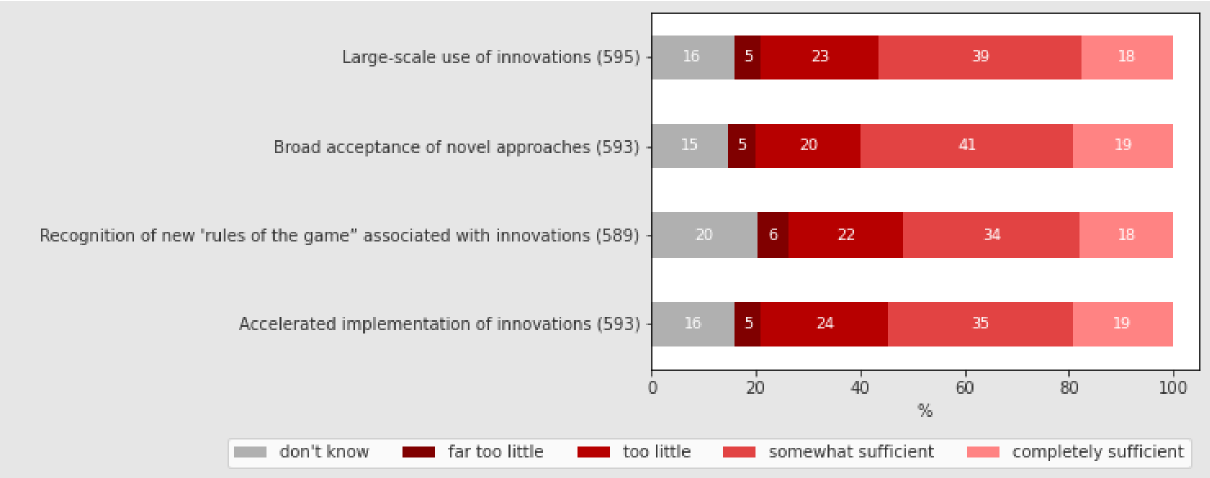


Figure 199 Q42: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Expansion of new fields of innovation relevant to the Green Transition.

With regards to the Replication of innovative solutions relevant to the Green Transition in new contexts, slightly more than half of the respondents consider that H2020 projects respond somewhat or completely sufficiently to the different aspects. Application of innovations in other places or regions comes first with 55% followed by re-interpretation and adaptation of solutions in other places (53%); transfer of innovation into other application areas (51%) and lastly by transfer of innovation into other contexts (50%). Slightly more than 20% think the response to these needs is too little or far too little and around one-quarter of the respondents do not have an opinion about that.

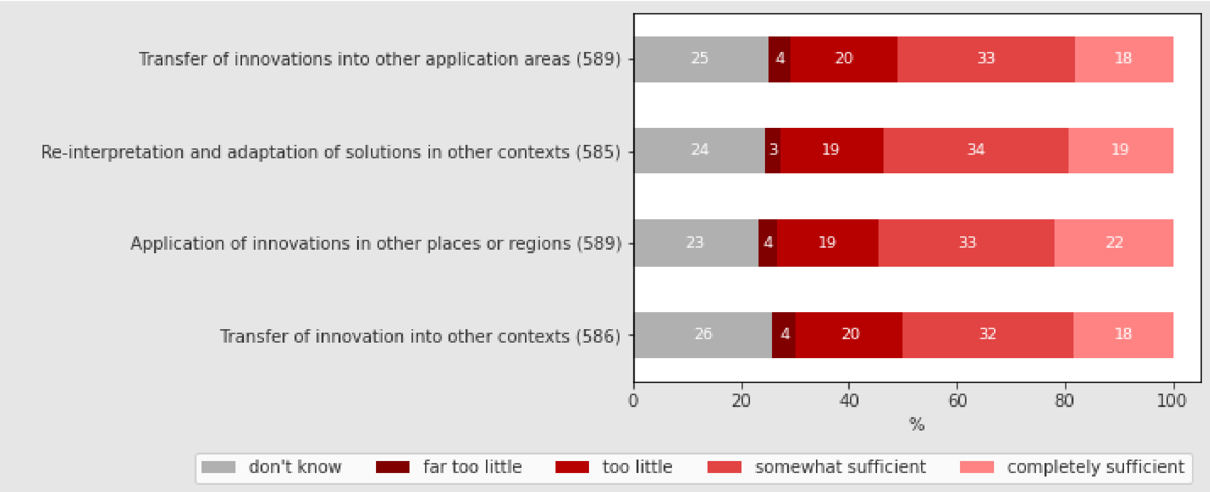


Figure 200 Q43: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Replication of innovative solutions relevant to the Green Transition in new contexts.

With regards to the Dissemination and diffusion of innovative solutions and concepts relevant to the Green Transition, between 52% and 74% of the respondents consider that H2020 projects respond somewhat or completely sufficiently to the different aspects. Open communication of novel solutions comes first with 74% followed by widespread dissemination of new, innovative ideas (71%); transfer of knowledge beyond the boundaries of one's field of knowledge (64%) and lastly intensive discussions of innovations from other contexts (52%). Around 20% think the response to these needs is too little or far too little and between 10% and 19% of the respondents do not have an opinion about that.

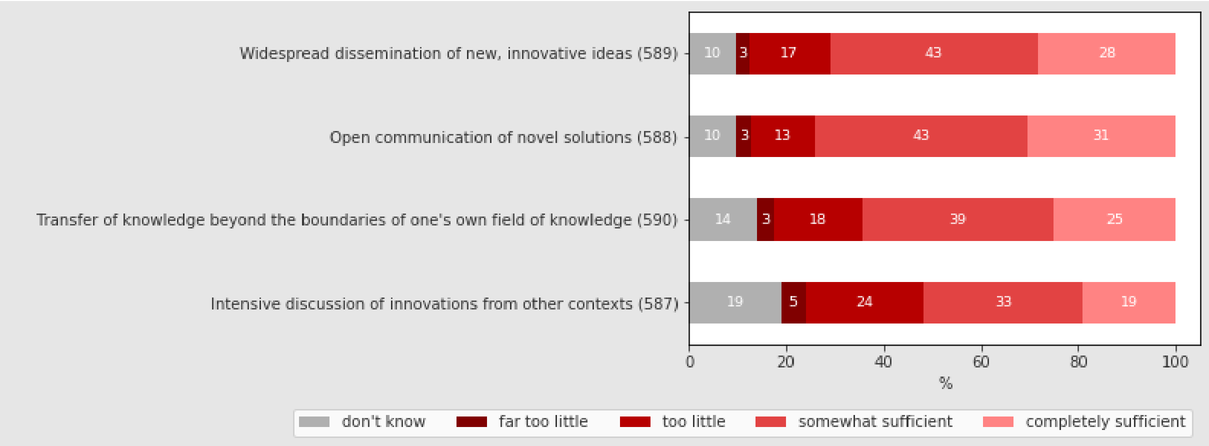


Figure 201 Q44: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Dissemination and diffusion of innovative solutions and concepts relevant to the Green Transition.

With regards to the Institutionalisation of new strategies and norms relevant to the Green Transition, between 36% and 44% of the respondents consider that H2020 projects respond somewhat or completely sufficiently to the different aspects. Establishing new, common conditions or norms comes first with 44% followed by an institutionalisation of new solutions (43%); establishing new rules of conduct (41%) and lastly establishing of new legal and regulatory foundations (36%). Between 25% and 31% think the response to these needs is too little or far too little and between 29% and 33% of the respondents do not have an opinion about that.

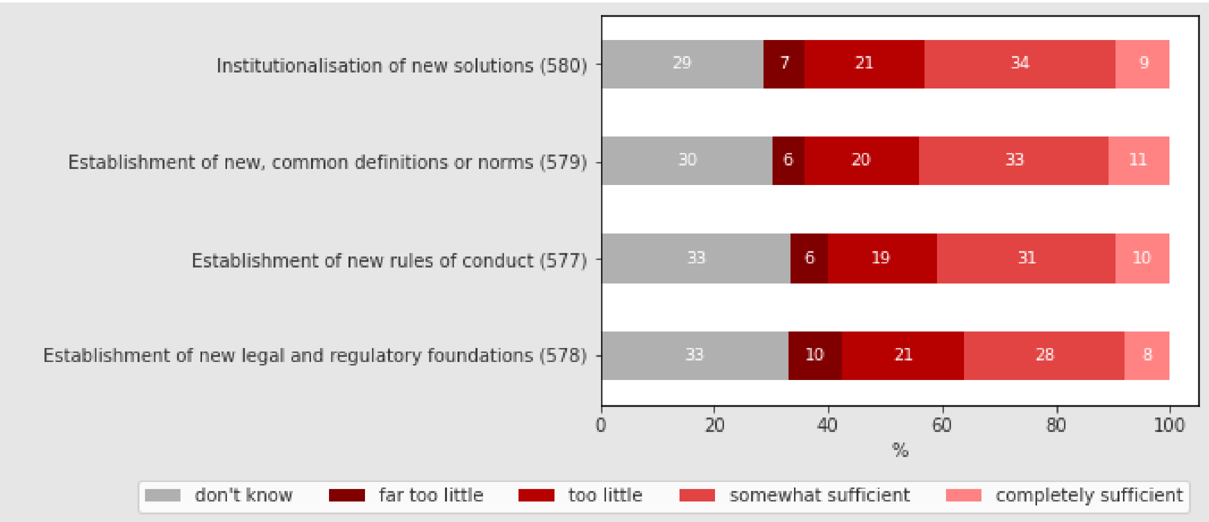


Figure 202 Q45: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Institutionalisation of new strategies and norms relevant to the Green Transition.

4.3. Opening up and unlocking regimes

With regards to Breaking up outdated structures and strategies relevant to the Green Transition, between 40% and 61% of the respondents consider that H2020 projects respond somewhat or completely sufficiently to the different aspects. Open-mindedness of established actors for new ideas comes first with 61% followed by opening the system to new strategies (59%); breaking up outdated processes (44%) and lastly shaking up the established system through radical innovation(40%). Between 23% and 40% think the response to these needs is too little or far too little and between 15% and 20% of the respondents do not have an opinion about that.

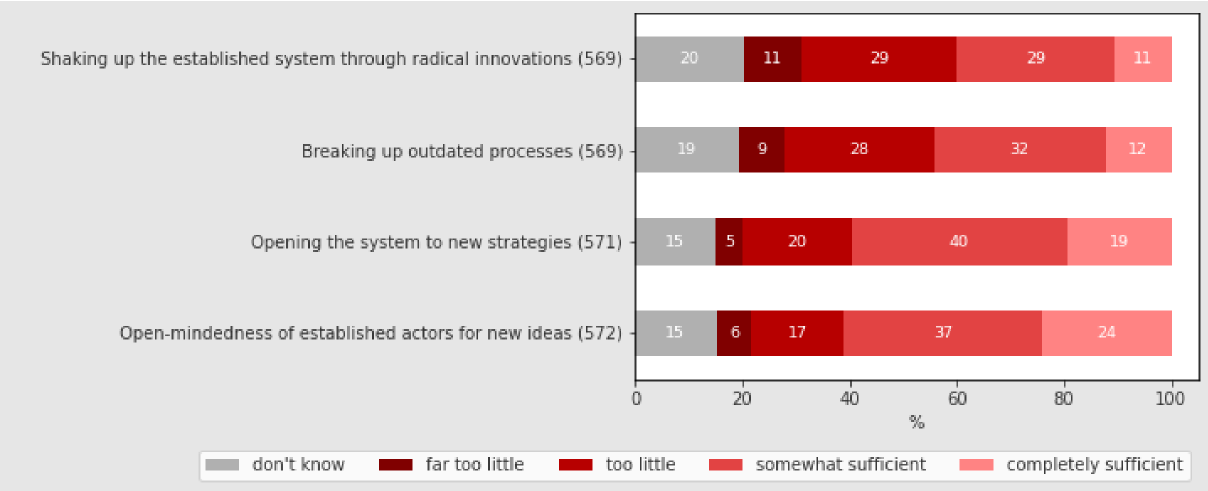


Figure 203 Q46: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Breaking up outdated structures and strategies relevant to the Green Transition.

With regards to Abandoning outdated habits and rules to enable the Green Transition, between 40% and 56% of the respondents consider that H2020 projects respond somewhat or completely sufficiently to the different aspects. The willingness of established actors to engage in new ways of solving problems comes first with 56% followed by questioning the usefulness of accepted solutions (54%); acceptance of risks that innovations entail (53%) and lastly unlearning of old rules and habits (40%). Between 25% and 34% think the response to these needs is too little or far too little and between 18% and 26% of the respondents do not have an opinion about that.

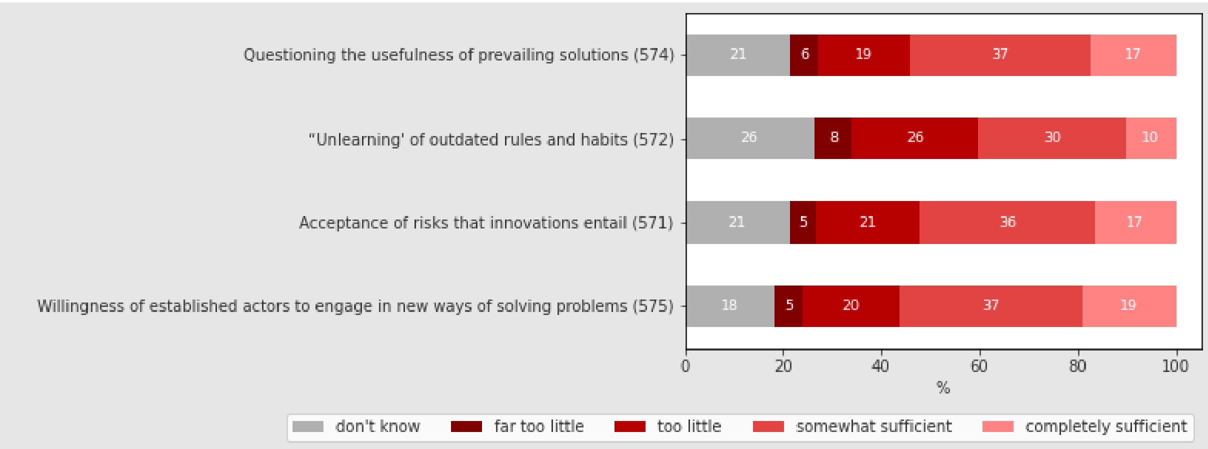


Figure 204 Q47: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Abandoning outdated habits and rules to enable the Green Transition.

With regards to the Exchange between "old" and "new" areas of knowledge relevant to the Green Transition, between 46% and 59% of the respondents consider that H2020 projects respond somewhat or completely sufficiently to the different aspects. The exchange between "old" and "new" areas of knowledge comes first with 59% followed by networking between pioneers and established players (50%); opening up rigid patterns of cooperation to new actors (47%) and lastly by opportunities for (46%). Between 25% and 34% think the response to these needs is too little or far too little and between 18% and 26% of the respondents do not have an opinion about that.

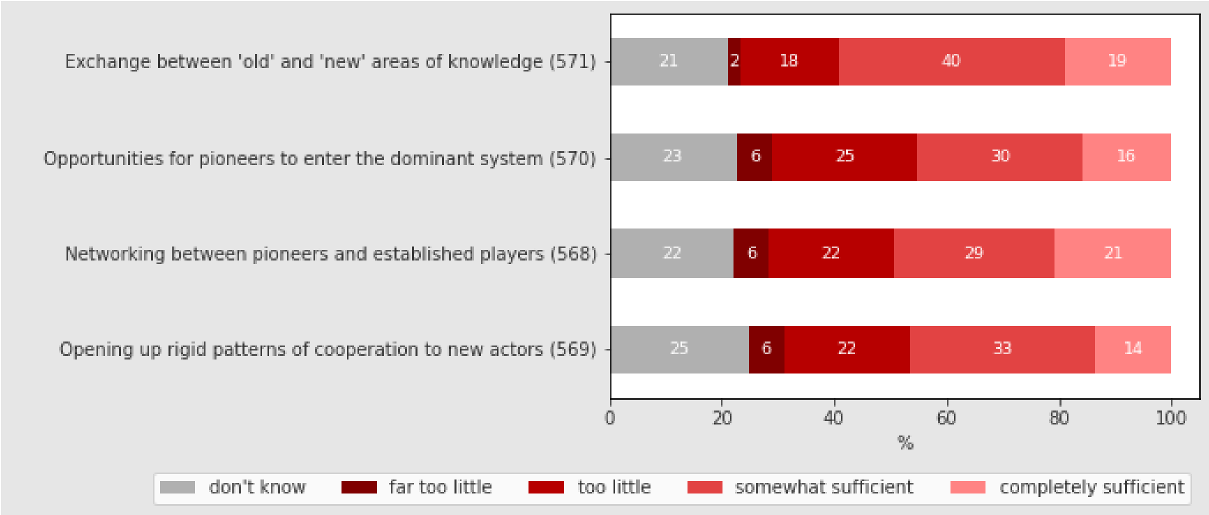


Figure 205 Q48: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Exchange between "old" and "new" areas of knowledge relevant to the Green Transition.

Between 43% and 60% of the respondents answered that H2020 projects responded somewhat or completely sufficiently to all four needs. ‘The recognition of the need for action due to new development’ comes first with 60% followed by the remaining three needs with 47%-43%.

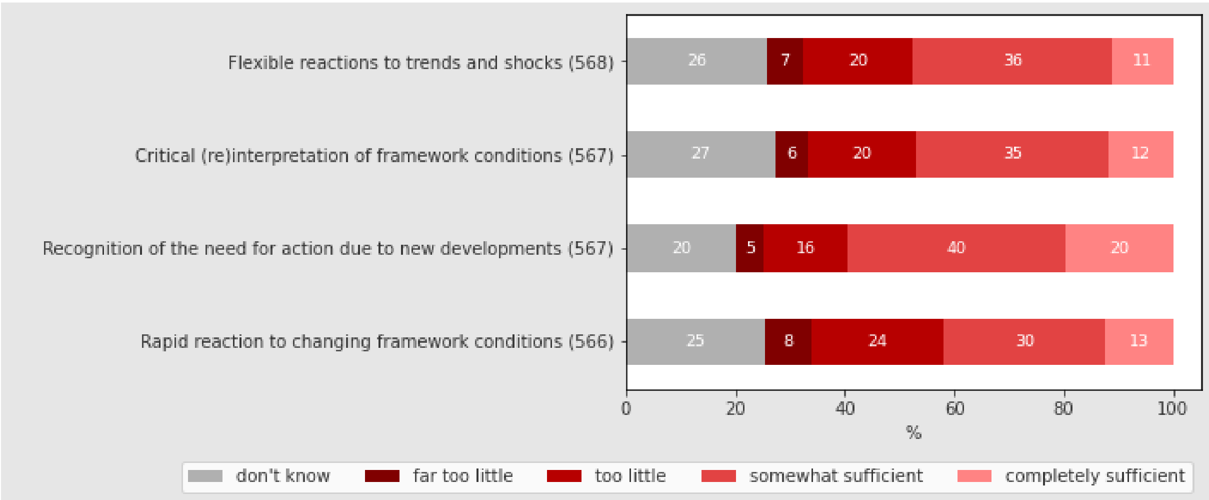


Figure 206 Q49: In your opinion, as a contributor to a Horizon 2020 project, to what extent did Horizon 2020 respond to the following needs of a Green Transition in your field of expertise? Flexible response to changing framework conditions to enable the Green Transition.

ANNEX VIII: RESULTS FROM THE INTERNATIONAL BENCHMARKING

Table 24: List of acronyms.

Acronym	Meaning
ACRP	Austrian Climate Research Programme
AIT	Austrian Institute of Technology
AWS	Austria Wirtschaftsservice Gesellschaft
BMBF	Federal Ministry of Education and Research
BMK	Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology)
CCCA	Climate Change Centre Austria
CDI	Citation Distribution Index
DDA	Average of the relative diversity of disciplines in the research backgrounds of different authors of a given publication
DDA	Multidisciplinarity Index
DDR	Average of the relative diversity of disciplines in the references of a given publication
ERA	European Research Area
ERA	European Research Area
EU27	European Union (countries)
FFG	Forschungsförderungsgesellschaft (Austrian Research Promotion Agency)
FONA	Forschung für Nachhaltigkeit
FP	Framework Programme
FRIKLIM	Free Climate Research
FWCS	Field-weighted citation score
FY	Financial Year
GHG	Greenhouse gas
GPRA	Government Performance and Results Act
H2020	Horizon 2020
HTS	High-Tech Strategy
IPCC	Intergovernmental Panel on Climate Change
JPI	Joint Programming Initiative
KLIEN	Klima- und Energiefonds (Climate and Energy Funds Austria)

Acronym	Meaning
KPC	Kommunalkredit Public Consulting
MoST	(Austrian) Ministry of Tourism and Sustainability
NOK	Norwegian krone
NSF	National Science Foundation
OA	Open Access
PROSYS	Earth-system Analysis and Risk Assessment
RCN	Research Council Norway
RIS	Regional Innovation Scheme
RTD	Research, Technology and Development
SCHIG	Schieneninfrastruktur Dienstleistungsgesellschaft (rail infrastructure services)
SDG	Sustainable Development Goals
SME	Small and Medium Enterprises

ANNEX VIII : RESULTS FROM THE INTERNATIONAL BENCHMARKING

The international benchmarking exercise, as part of the overall Green Transition Evaluation, aimed at identifying lessons learnt from best practices worldwide supporting research and innovation and putting in perspective the efficiency and effectivity-oriented performance of the H2020 Framework Programmes in the area covered by the study.

In Phase I, the benchmarking exercise focused on efficiency and effectiveness, to a lesser degree also on relevance, and on providing a qualitative comparative assessment of H2020 with the four international benchmarking cases which were selected in accordance with the Commission.

The Green Transition is the lens through which the evaluation exercise is regarded. The transition implies a strong connection to society. Therefore, the qualitative comparison with H2020 foresees as dimensions of interest (a) the strategic development which ought to reflect the adaptive capacity to react to a changing or emerging global situation, (b) the uptake of R&I results, and (c) networking and infrastructure. Transdisciplinarity serves as a fourth, cross-cutting dimension.

All cases have been selected jointly with Commission staff and are of specific interest for the international benchmarking because they explicitly address, among others, issues of transformative change and governance, as well as specific support for policy-makers. The results are expected to shed light on the above-described outcome dimensions as well as on the evaluation criteria of Phase I, i.e., effectiveness, efficiency, and relevance.

1. Introduction and overview

1.1. Objectives of the international benchmarking

The international benchmarking aims at identifying lessons learnt from best practices worldwide supporting research and innovation and putting in perspective the performance of the Framework Programmes in the area covered by the study. In Phase I, the benchmarking exercise will focus on efficiency and effectiveness, as well as on relevance, and provide a qualitative comparative assessment of H2020 with the four selected international benchmarking cases.

The chosen international cases are of specific interest for international benchmarking because it explicitly addresses, among others, issues of transformative change and governance, as well as specific support for policy-makers.

1.2. Benchmarking approach

Typically, benchmarking involves the following steps, which we adapted for our international benchmarking pilot study: identification of problem areas; identification of similarities with similar interventions in the field; survey of measures and practices; implementation of new and improved practices. Learning and improvement are at the heart of a benchmarking exercise.

The acronym IDEAS captures the action steps of the benchmarking:

- **I**nquire: investigation of possible benchmarking areas
- **D**ecide: Selection of a relevant area
- **E**xpand: Exploration of key features of the area – causes, effects, and solutions
- **A**nalyse: Seeking expert opinions
- **S**pecify: Interpretation of results for the way forward

In the case of the international benchmarking done in Phase 1 of the Green Transition Evaluation, which focuses on ex-post evaluating H2020, two evaluation criteria are key: **efficiency** and **effectiveness**. That said, considering the Green Transition perspective and the paradigm shift that happened during H2020, **relevance** was added as an additional criterion of interest.

A pool of potential benchmark cases was determined by applying a set of selection criteria[24]. In accordance with the client, four international cases were chosen to be covered by the study (cf. Table 24).

Table 25. International benchmarking cases selected for Phase I of the Green Transition Evaluation.

International Benchmarking	Case	Country	EU	Beyond EU
Case I (pilot)	ACRP – Austrian Climate Research Programme	AT (Austria)	✓	
Case II	KLIMAFORSK	NO (Norway)		✓
Case III	FONA – Forschung für nachhaltige Entwicklung *(Research for sustainable development)*	DE (Germany)	✓	
CASE IV	NSF – National Science Foundation	US (United States of America)		✓

1.3. Methodology and case study structure

All case studies follow a common methodology which comprises the following methods:

- Desk research: evaluation studies of previous years, online presence of the case, additional background and relevant policy papers about the umbrella institution and its mandate, funded projects, and beneficiaries.
  - Identification of possible benchmarking areas
- Internal reviews, identification of interviewees → Selection of relevant thematic areas in alignment with FP8 (Horizon 2020), focusing on the green transition (i. e. aiming at initialising structural and lasting change) and, with regard to key topics in FP9 (Horizon Europe).
- Data collection phase: Interviews, focus groups, bibliometric data → Expansion to further identify good (and bad) practices and understand causes and effects.
  - All obtained qualitative data will be processed to assess both content and narrative framing – the way certain actors frame issues related to efficiency, effectivity, and performance – to provide a comparable basis for comparison across benchmarking cases.
  - The qualitative data were complemented by and interpreted considering the results of a quantitative analysis undertaken by Science-Metrix and additional desk research. An analysis involves expert opinions and quantitative data to further complement and increase the robustness of the objectives of the evaluation results.

[24] objectives and scope of the case; target groups; budget; governance; type of R&I targeted; policies and instruments; positioning at national/regional and international level; organisation; implementation processes; identification and tackling of state-of-art scientific, technological, and/or socio-economic problems; SDG orientation; monitoring and evaluation of performance

- Dimensions for qualitative comparison with H2020: given that the lens of the overall evaluation exercise is the *Green Transition*, which implies a strong connection to society, the following dimensions for the qualitative comparison with H2020 are foreseen:

  – *strategic development*, adapting to changing/emerging global situations
  – *uptake of R&I results*
  – *networking and infrastructure*
  – *transdisciplinarity* as a cross-cutting dimension

1.4. Challenges and limitations for carrying out the benchmarking

One of the main limitations we encountered was the limited data availability, mostly linked to the insufficient project and programme monitoring, which is something urgently to be improved, made transparent (publicly available) and harmonised across Europe for better climate change impact, resilience, mitigation, and adaption research. For the Norwegian benchmarking case, this was mainly evidenced through a lack of available interviews; in the NSF benchmarking case, little literature (and evaluation studies) was accessible or available; in the FONA case, a major roadblock was set by the concerned German ministry due to internal political restructuring. For the ACRP case, interviewees were available, yet more preparation and overall study time would be required due to the extreme work overloads regarding programme admin staff in all cases.

In three cases data collection took place during the summer months (the pilot was carried out in April/May). However, this timing severely affected the availability of external experts in Norway. As for the NSF benchmarking case specifically, few relevant evaluation reports were available. This involves the fact that within the NSF organisation, there is not a distinct overarching "green transition" division and/or focus.

Therefore, the desk study took much longer than expected. In addition, for the analysis, we had to rely on a wide range of other, partly related, documents, which made data triangulation more difficult. In terms of data collection from interviewees, we encountered difficulties to identify and access interviewees. Generally, few people were willing to be interviewed. Reasons we heard related to their unfamiliarity with Horizon 2020 and people not feeling in a position to provide an overview of NSF's activities.

2. Synthesis of evidence

2.1. Benchmarking Case 1 (pilot): ACRP – Austrian Climate Research

2.1.1. Introduction to the international benchmarking pilot case: the ACRP

The Austrian Climate Research Programme (ACRP) is the first in a series of four international benchmarking cases and, as such, our pilot case.

The ACRP is under the auspices of the Climate and Energy Funds Austria. It had been initiated in 2008 according to its legal mandate which emphasises research on nationally relevant forms of impact of global climate change. In addition, it focuses on the analysis and exploration of climate change adaption mechanisms, including interdisciplinary and transdisciplinary dimensions of vulnerability, risk management and related policies in the field.

2.1.2. Study constraints

For this benchmarking pilot study, several constraints were to be considered. First, the ACRP and its operating entity as of yet, KPC, have no direct mandate for proper programme monitoring. That is, neither are encompassing statistical data collected on an annual basis nor are any other measures of progress made available publicly. There is a list of data regarding outcomes and follow-up procedures circulating internally between KPC, KLIEN, and BMK, but access to this list has not been granted. Second, the ACRP at KLIEN is grossly understaffed and thus in many regards operationally and programmatically run part-time by a single person.

That said, the outcomes of the evaluation study 2019 with regard to the ACRP's overall performance provided us with **concrete entry points for our semi-structured interviews** with members of the management board and steering committee. We understand that given our overall theme of green transition and climate change adaptation/mitigation, a **focus on improving social impact through effective communication, differentiated objectives, and targeted instruments** is vital. Therefore, we focused during interviews on the highlighted improvement areas to pinpoint and identify lessons learnt and potential benchmarks for similar funding programmes in Europe.

Guiding questions for the interview of stakeholders as well as a list of interviewees are included in the annexe.

In addition, we conducted an in-depth analysis of the material and (rather rudimentary) research project database available online. This includes the so-called KLIEN "guidelines" which set the stage for every annual call of the ACRP and present some of the thematic focuses, as well as their shifts over the years in response to (mainly) public policy interests.

2.1.3. ACRP background

The Austrian Climate Research Programme (ACRP) is one of the main funding programmes of the Austrian Climate and Energy Funds (KLIEN) and is deeply committed to achieving climate neutrality by 2040 and, by 2030, to generate 100 % of the nationally consumed energy by renewable resources. KLIEN supports the implementation of the goals of domestic climate policy and the development towards a sustainable energy system. The four intervention areas of the Fund are:

- Energy transition
- Mobility transition
- Climate Change
- Awareness Raising

Since its establishment in 2007, the KLIEN (Climate and Energy Funds) has developed around 111 different funding programmes. The Fund also participates in SOLAR-ERA.NET. KLIEN is supported by operational funding and research agencies such as the Austrian Federal Promotional Bank (AWS), the Austrian Research Promotion Agency (FFG), and others.

2.1.3.1. Legal Basis and Governance

The legal basis for ACRP is the RTD Guidelines according to § 11, subparagraphs 1 and 2 of the Research and Technology Funding Act of the Federal Ministry of Transport, Innovation and Technology as amended on January 1, 2015, and extended by the Federal Ministry of Climate action in 2020. The programme owner is the Climate and Energy Fund (KLIEN). The ACRP calls are currently operatively implemented by the Kommunalkredit of Public Consulting GmbH (KPC). To be precise: Until June 2022, the operational organization of calls, submission handling, peer reviews and funding payments has been in the hands of KPC, an external agency linked to the private and public sector, which for years has also overseen running the operations and funding disbursements of several KLIEN programmes and activities. The knowledge of, and proximity to, the scientific community – in particular of the carefully extended project proposal peer reviewers' database – at KPC has been built up over the years, ensuring stability and proper follow-up procedures by maintaining the main responsibility for administration and operation within the hands of the same few persons (almost) since the first round of calls of the ACRP.

2.1.4. Thematic Orientation of ACRP

ACRP supports research on the impacts of climate change on ecosystems, specific economic sectors, health, social aspects, etc. and the resulting adaptation requirements, including inter- and transdisciplinary vulnerability studies, risk management approaches and policy analyses. The program aims to enhance Austrian research competence in the area of climate adaptation and mitigation and to integrate it more strongly into international research endeavours. The ACRP is by far the largest research programme of its kind in Austria.

2.1.5. ACRP objectives and KLIEN (Klima- und Energiefonds)

The ACRP focuses on research on climate change and climate actions, adaptation, mitigation, and their mutual interrelation. The intent is to provide scientific background for the implementation of the Austrian strategy for adaptation to climate change, the National Energy and Climate Plan, and the Paris Agreement in Austria.

These objectives require concerted efforts across all sectors for enormous rethinking and transitioning towards different energy-related economic and social models, of which the KLIEN (Klima- und Energiefonds; Engl. Climate and Energy Funds) is fully aware. Located at the BMK (Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology), KLIEN aims at propelling novel climate-friendly measures, including energy-saving technology, and climate change adaptation, as well as mitigation, between emerging so-called *model regions* at the provincial administrative level (Bundesländer), municipalities and urban spaces within Austria. The ACRP emerged out of a semi-private initiative from the scientific community reclaiming research space and funding within the KLIEN in 2008. In this regard, both KLIEN and ARCP, according to its General Managers, aspire to deliver innovative beacons for the national and international community in the field of climate protection, yet “made in Austria”.

2.1.6. ACRP Target group

The programme targets different kinds of research organisations and science-oriented organisations. Research areas include, among others, natural sciences, social and economic sciences, and legal and technical topics that usually have to be solved in interdisciplinary and partly transdisciplinary ways. Project partners are not limited to Austrian research institutions and can include foreign researchers as well as businesses and other practitioners as long as a full publication of results is guaranteed.

2.1.7. Previous evaluations and lessons learnt

The ACRP has been evaluated at the national level in 2009 and 2019. Both studies present relevant basic data for this international benchmarking pilot exercise, in particular, the 2019 evaluation study which positively highlights the ACRP's performance relate to the constant interaction between the steering committee during the project cycle, which aims at further improving research outcomes; on the other hand, this could be negatively perceived as exerting control. This interaction has been described by some interviewees as unique in that other international funding programmes in the field do not have it (Evaluation study 2019, chapter 6.3). Negative findings refer to the weak overall monitoring of data and outcomes, in addition to science communication – these, so the study conclusion, should be improved by fostering the ACRP's governance structure. This is particularly relevant since some of the ACRP's funding pillars explicitly aim at the creation of guidelines and handbooks for decision-making that are rather loosely made available and, back in 2019, were not broadly promoted/communicated at a societal level later on. In addition, while being esteemed as socially highly relevant, the ACRP's research output has been described as conflicting with internal university and academic performance assessments which typically focus on article publications (only).

In 2020, the ACRP´s management board responded to earlier criticism from the Ministry of Tourism and Sustainability (MoTS) – which generally claimed little say in the steering committee – by including two permanent experts from the ministry. This way, political or at least governmental influence has been strengthened rather than diminished. Yet, this influence has not extended as far as selecting research proposals or themes to be funded, as the 2019 study underscores.

Generally, the 2019 evaluation study’s main findings listed the following improvements as recommendations for the next years, without spelling out priorities:

- **Overall budget increase** after a programmatic shift from fewer long-term funded research to more mid-term funded projects in 2018.
- **Differentiation of programme objectives**, particularly with regard to capacity-building, practice relevance, and evidence-driven information for (political) decision-making.
- **Expansion and differentiation of funding instruments**, especially for fostering research communication and long-term availability of results, to foster impact.

- **Refinement of the selection procedures**, including measures for applicants at different career stages and reviewers from outside traditional academic settings.

- **Governance** structure

- **Communication**, with an emphasis on differentiation by stakeholder in the decision-making processes.

2.1.8. Relevance

Arguably, according to international policy recommendations (IPCC, EU Green Deal, etc.), the overarching objective of climate and climate impact research is, beyond data collection and periodic updates thereof, to actually and concretely contribute to the green transition, the achievement of the Sustainable Development Goals (SDGs) and, in the case of Austria, to fulfilling the National Climate Adaptation Strategy.

In this sense, the BMK's KLIEN and its funding pillars are uniquely positioned by combining and working across the public, private, and research sectors. It launched, for instance, an internationally recognised vanguard strategy, including the aim of 100 % renewable energy by 2030. Energy should be sourced from centralised and de-centralised origins, for which climate and energy communities are key. Legal and structural provisions (funding, networks, adoption of policies, etc.) have been met to realise this declared objective.

According to our interviews, and this has been confirmed across all our interviewed stakeholders, the ACRP is however rather detached from these hands-on transformation initiatives at the Austrian sub-federal and municipal level. While there have been a few projects in the past whose results and outcomes were relevant for climate adaptation projects and energy communities – especially from the social sciences, e. g. interrogating motivations for subscribing to public green transition credits and related consumer decisions – the ACRP and its strategic orientation is aligned with the excellence aspirations of the scientific community rather than concrete applied transformation requirements and public policy in the field.

In other words, there is little cross-breeding and influence between the ACRP and KLIEN's overall programmes. Reasons are certainly linked to diverging needs of scholarly work and excellence aspirations in relation to socio-political realms. But they are also part of, what we analysed as a foundational tension, as well as a deeper-lying social conflict over very concrete interests and economic positioning. For instance, concrete service-providing attempts by CCCA scientists at the municipal and provincial level, have rapidly got under attack, because of being perceived as threatening the thematic leadership of BMK's expert, on the one hand, and on the other, the interests of local businesses of transition advisers and related services, frequently attached to, or under the influence, of local politics and its immediate interests.

There is also another dimension of unmet relevance which needs to be addressed: while the ACRP has managed to establish and foster a relevant scientific community, little has been done to better implement and embed the ACRP and related KLIEN research funding (Energy, Smart Cities, START, etc.) between larger international funding and exchange programmes, in particular, by the European Union. But also beyond, since climate change – from an organic perspective of autopoietic systems (e. g. Maturana and Varela, 1975) – is of global concern. Mutual climate impact and interlinked effects require to be studied from a systemic planetary perspective, as highlighted by several approaches, most famously those following the approach of planetary boundaries (Rockström et al, 2009). Several of our interlocutors confirmed that international partnerships within ACRP-funded projects are regularly limited to the European research landscape and also thematically narrow (e.g., almost not including research related to the oceans, due to Austria being a landlocked country).

This certainly reflects diverging policy priorities and interests between the multilateral and national funding levels. For instance, Austria still lacks complementary public budget provisions and further temporary staff-reserving mechanisms for co-funding large EU research and adaptation projects, as our expert interviewees from the ministries pointed out. Also, within universities, large-scale EU-funded research with an extremely competitive positive approval rate is frequently perceived during the proposal preparation phase as unnecessarily binding staff and resources with a highly uncertain outcome.

Yet, in the sense of bringing about a green transition, we argue that this situation also points to necessary improvements with regard to better integration of and interconnection with international and national and regional research programmes, as well as applied transition projects. Additionally, this would involve a much better, public transparent monitoring and knowledge-transfer mechanism of the ACRP, for instance, to achieve full socio-political relevance and thus increase media attention.

2.1.9. Effectiveness

The focus of the program is on research on the national characteristics and effects of climate change, including the adaptation requirements to inter- and transdisciplinary vulnerability studies, risk management approaches and policy analysis. In a somewhat uneasy combination, aims to satisfy several needs according to its stakeholder community: The program aims to (a) improve Austrian research competence; (b) expand this sector and involve it more closely in international research, and (c) to deliver the decision-makers in politics and administration scientifically sound evidence-based decision-making insights.

To do so, the ACRP has – until 2021 – published 14 competitive annual Calls and supported over 250 projects with a total volume of approx. 100 million Euro. Each call results in approx. 80 to 90 proposal submissions.

This tension plays out at several levels of the ACRP's overall performance. To name just a few examples that emerged through our interviews:

- Divergent temporalities and needs: while policy-makers require quick assessments and answers, ACRP-funded, excellence-oriented projects last on average for three years (and are frequently perceived as too short for delivering excellent scholarship, particularly after the project period reduction of 1 year in 2020). However, according to our policy interlocutors, also three years would mostly be too long according to their specific needs and requirements. In response to this tension, in 2022, "ACRP Impact" has been launched to fill the gap of much-needed short-term applied projects, responding to emerging knowledge voids. ACRP Impact should in addition serve as a second preliminary testing site for larger ACRP proposals later on.

- Project size, innovation and orientation: In a similar vein, the SC has a track record of rejecting projects based on criteria of absolute scientific innovation or novelty, not necessarily according to national standards of novelty (i. e. permitting the replication of a certain study design or methodology for the Austrian context). In addition, accepted projects typically involve a focus on the international scientific community beyond national frontiers, while the funding entity seeks to maintain a pro-Austrian focus according to its specificities and needs. Accordingly, policymakers would favour several smaller and quick projects instead of large and more international projects – a tendency observed by our interlocutors also for the European research funding level: scientist community members declared their interest against larger European funding if only leading to larger consortia and longer projects, and as being generally in favour of strengthening national funding programmes, taking regional specificities into account and presenting lower entry levels for younger scholars, if this tendency continues.

- Independence versus political influence: Scientific excellence requires political independence and non-interference. However, policy-making, especially within a generally still rather hostile policy environment regarding pro-evidence-based decision-making, requires safeguarding certain spaces for proposing thematic priorities and launching specific calls or direct channels of communication with researchers. The specific construction of the ACRP manages to strike a delicate balance between these different logics and realms, but cannot escape constant criticism regarding, seemingly, too little effort between its main stakeholder groups given this basic tension. In response, for instance, KPC's operational processing will be handed over to the Austrian Research Promotion Agency (FFG). FFG is the single national funding and handling agency for publicly commissioned or tendered research, yet in fact, oriented towards industrial research and pro-business development in Austria. The effect of this transition on the ACRP is yet to be seen. However, some of our interlocutors are already alert to a changing perception within the climate research community, alluding to losing ownership – and thus overall relevance – with regard to "their" research platform.

In conclusion, the ACRP's tools and instruments have been evaluated in 2019 as both sufficiently effective (in terms of achieving to foster a relevant scientific community and their competencies) and insufficiently effective at the same time, given the (overly) broad mandate of the programme. This is furthermore complicated by the country's predominant policy and research focus on pro-technological and, mostly, pro-market-based adaptation in the field of climate change responses, and less on mitigation itself, not to mention the Green Transition.

2.1.10. Efficiency

As regards the evaluation of project proposals, a first check for formal criteria is being conducted by KPC staff members upon proposal submission. Next, those not satisfying the formal criteria are sent back for resubmission within close deadlines, resulting in a regular acceptance rate of almost 100 %. In a third step, proposals are grouped thematically upon which the KPC proposes three reviewers (out of its database) for each proposal. Project teams are called upon to provide the name and contact of a fourth reviewer who is double-checked by KPC and then entered into the database for the next year's call.

Finally, KPC submits its proposals to the SC and KLIEN who review the proposed reviewers and, if necessary, make changes to the pre-selection. KPC, then, is in charge of contacting the reviewers and processing the review phase, including payments and communications to the project applicants. After reviews, positively reviewed projects need to be approved by the SC – which, according to some of our interviewees, tends to select rather "conservatively" according to the overweight of the natural sciences, and generally less "innovatively". The BMK receives only the anonymised abstracts of selected and not selected projects for funding and can issue additional recommendations but has no vote in the approval process. Most importantly the SC is said to decide according to scientific excellence standards and not necessarily according to policy needs in any given political, environmental or economic cycle. There is a relevant exception, though, and this concerns foremost the direct calls for national climate assessments enacted through the ACRP's annual calls, which were developed under the influence of the presence of IIASA in Austria, and the membership of several of its staff members in the Intergovernmental Panel on Climate Change. The proposal success rate over the years is between 20 and 30%, highlighting the competitive character of the programme.

In terms of limited in-house monitoring, funded projects have to submit an interim report and a final report (both made publicly available on the ACRP website). In addition, all funded projects are voluntarily called upon submitting an outcome report one year after the finalization of their projects. This data is stored internally only.

The ACRP has been evaluated after its 3rd call and again after its 9th call. According to these evaluations, the thematic scope of the ACRP has remained stable over the years. At the same time, the fundamental tension between its two main objectives seems to have intensified: Fostering excellence in academic research and networking, on the one hand, versus providing relevant evidence to acute problems and challenges to decision-makers.

This is aggravated by the following issues: First, the ACRP represents the sole relevant funding programme in the field of climate and climate impact research in Austria, particularly including an interdisciplinary and even transdisciplinary problem-oriented scope. Other major science funding institutions in Austria are primarily focused on basic research according to disciplinary excellence and, overwhelmingly, based on single-scholar career profiles. Also contrary to neighbouring Switzerland and Germany, the national meteorological institution (ZAMG) in Austria plays no role in research funding or infrastructure at all, beyond the provision and hosting of climate data.

Second, the understaffed ACRP team within KLIEN and the ACRP's institutional set-up between SC and Advisory Board (currently suspended and to be renewed in 2022) can only guarantee a certain level of scientific excellence but cannot ensure greater social visibility and relevance of climate research as such in times of accelerated climate change and urgently required encompassing deep green transitions. According to the 2019 evaluation study, the current steering model of the ACRP is overstrained with issues of agenda-setting and ensuring socio-political relevance.

One of the key successes of the ACRP is the establishment and cultivation of a highly interdisciplinary steering committee.

2.1.11. Summary of ACRP evaluation criteria

2.1.11.1. Relevance

According to science community members and policymakers alike, mitigation has been the focus of the ACRP in earlier years, but this focus shifted more recently also because of the adoption of the Austrian Strategy for Adaptation to Climate Change in 2013. This keen strategy has been lauded as far-reaching and encompassing, yet concrete measures and impact are lagging, especially at the federal level. Policy-makers have therefore an interest in achieving concrete adaptation success, also reflected by the KLIEN programme "KLAR!", targeting adaption model regions in Austria. It is not by coincidence that, according to our KLIEN interlocutors, thematically open ACRP research outcomes are receiving the most attention within the KLAR! programme, while otherwise being rather irrelevant for the majority of KLIEN's applied transition and transformation programmes. In terms of knowledge transfer some of the ACRP-funded projects are featured in a BMK/KLIEN in-house publication, circulating among the various KLIEN initiatives, but supposedly, according to our interviewees, rather rarely taken up by concerned potential partners.

Therefore, from a Green Transition perspective, ACRP's relevance can only be regarded as average. With regard to climate research, the relevance of ACRP would be regarded as considerably higher.

2.1.11.2. Effectiveness

As stated above, the final assessment regarding the effectiveness criterion will be provided as soon as the synthesis results of parallel ongoing H2020 evaluation studies are available. For the time being, a quantitative comparison based on scholarly output, i.e., publications in scientific journals, conference proceedings, books, etc., offers several insights. These quantitative results were provided by Science-Metrix, based on a tailor-made analysis[25] of the publications that can be linked to the ACRP or H2020.

To **benchmark the ACRP against H2020**, the statistically robust findings are presented along the following dimensions:

- International co-publication output
  - The average number of unique countries per publication in **H2020 publications** was always **above** the corresponding figures found in **ACRP publications**, at statistically robust levels.
  - In terms of **shares of authorships**, **H2020 publications** tended to have **lower** proportions of EU27 and EU27+UK authorships than **ACRP publications**. H2020 publications, however, had higher shares of authorships taken up the RIS, Associated Countries and Third countries aggregates than those found in ACRP publications (for instance, a normalised share of RIS authorships at 15.7, against 4.6 for ACRP papers).
  - Combined, findings on the 1) ICR, 2) average number of countries per paper, and 3) average share of authorship per paper indicators do suggest a **more internationalised and diverse profile in co-authorship for H2020 papers as compared to ACRP papers**.
- Cross-disciplinary research
  - Most differences between H2020 and ACRP scores on cross-disciplinarity indicators are not statistically robust. That said, measurements for both H2020 and ACRP publications on these dimensions are above the global level with scores between 1.2 and 1.6.

[25] A subset of Austrian researchers in Scopus was identified that had contributed to both ACRP-funded publications and H2020 publications. It was not possible to determine whether those researchers had been directly attributed funding as part of these two programmes, or whether they had simply contributed to publications supported by these programmes through the contributions of other authors. A total of 187 H2020 publications with contributions from those Austrian researchers could be observed, and a total of 142 ACRP-supported publications with contributions from the same set of authors. Those two publication sets were mutually exclusive, that is, publications with both H2020 and ACRP funding were excluded from the analysis.

- On the normalised share of **highly multidisciplinary publications**, **H2020 publications score well below ACRP publications** at 1.4 (against 2.2). ACRP's score on this dimension is exceptionally high. The stability intervals for this comparison fall just outside the 95% threshold, however, ruling out any definitive conclusion.

- Science-industry co-publications

  - A share of 20% of H2020 publications included both academic and private firm authors, against 14% for ACRP publications. The added value of H2020 funding on this dimension was not statistically significative, however

- Citation impact

  - Note that only about 60% of ACRP publications and 45% of H2020 publications in the analysis here had been published in 2019 or before and therefore could be included in the citation impact assessment.

  - Citation **impact performances were much higher in Austrian H2020 publications against ACRP publications** on all indicators considered, although H2020's lead was not statistically definitive.

  - Most clearly, the H2020 score on the citation distribution index (CDI) was much above that of the ACRP publications (37 to 19; remember that the world level on this specific indicator is set at 0). The CDI indicator is a particularly robust citation indicator that takes into account performances by all papers in a given publication set, whereas other citation impact indicators can sometimes reflect exceptionally high performances by outliers.

  - **H2020 performances are more than nine times the global level in the share of publications falling within the top 5% most cited publications** in their respective subfield (HCP1% indicator). This compared to a share that was three times the world level for ACRP publications.

1. **Gender equality in authorships**

- **H2020 publications** included at least one female author in **86%** of cases, against **62% of ACRP** publications, a statistically significant lead for H2020 funding.

- Authorships on H2020 publications were taken up by women in 28% of cases, against 25% of cases for ACRP publications. H2020's lead is not significant here.

2. **Open access**

- A proportion of **90% of H2020 publications** was available under an **open access** modality, against **60% of ACRP publications**. H2020's lead was statistically robust.

3. **Policy-related uptake**

- The normalised share of H2020 publications cited in policy-related documents was <u>12 times</u> the world level, against less than <u>nine times</u> the world level for ACRP publications. This H2020 lead was not statistically definitive.

- For both H2020 and ACRP publications, policy-related uptake is well above world levels, indicating strong performances for this type of societal outcome.

- It can be noted that policy-related mentions of peer-reviewed publications should normally be allowed a four-year citation window or more, which has not always been the case for the publications assessed here.

4. **Beyond academia**

- In terms of altmetrics, differences in performances between the H2020 and ACRP publications sets are not statistically significant.

– Both H2020 and ACRP publications recorded levels of altmetric mentions ranging from two to six times the reference levels in a given subfield and year (except for Wikipedia mentions to ACRP publications). That is, **both H2020 and ACRP publications are likely to have been associated with greater levels of effort to increase awareness and online attention** towards the findings they contain.

To sum up the **key results of the quantitative analysis**:

- Austrian H2020 publication performances were well above world level and had, in general, a lead over ACRP in terms of a) the share of publications with at least one female author 2) the citation impact; and 3) open-access publishing.

- Austrian H2020 publications recorded more internationalisation and diversity in country participation than ACRP publications (the computation of global-level referents is not straightforward for these indicators, though).

- Both Austrian H2020 publications and ACRP recorded similar high scores well above word level in terms of 1) policy-related uptake 2) altmetrics 3) the share of science-industry co-publications.

- H2020 publications, while still scoring slightly above world levels on cross-disciplinarity indicators, scored equal to or below ACRP publications.

- In terms of gender equality, H2020 publications scored close to both the global level and ACRP level for the publication-level share of authorships taken up by women.

Globally speaking, the ACRP performs well in terms of the scholarly output that is generated, enabled by its funding. In terms of achieving its goals, the programme shows a fairly high rating.

It should be stressed here that, based on the study results – considering the ACRP evaluation results and the expert interviews conducted – the uniqueness of the ACRP is that it accommodates a broad range of interests and ensures highly interdisciplinary research.

2.1.11.3. Efficiency

In terms of efficiency, the ACRP fares well: given its constraints, it manages to process a rather large number of projects quite efficiently and even managed to grow and expand over several years, e. g. with regard to launching the new ACRP Impact funding mechanism. Furthermore, certain solutions to the persistent criticism of different stakeholders were found, e. g. the inclusion of the BMK experts in the SC (steering committee) sessions (subject to the right of the SC to sit temporarily without BMK members if desired) and their voice (but not vote) in the selection of topics for the annual call guidelines and other focuses of the KLIEN overall programme.

Based on study results, ACRP’s efficiency can be rated as high.

2.1.12. Outcome dimensions

2.1.12.1. Strategic development

In terms of strategic development, the key question is whether the programme kept abreast with and adapted to changing or emerging global situations, such as the Paris Climate Accords. In this regard, the ACRP fares quite well – it intends to provide scientific background for the implementation of the Austrian Strategy for Adaptation to Climate Change, the National Energy and Climate Plan, and the Paris Agreement in Austria.

While efforts towards the Green Transition have not been scaled up – in relative terms – by the ACRP as they have within H2020 (through the Green Deal), the former has indeed reacted to the shifting policy landscape. Although the ACRP highly stimulates interdisciplinary research, it could be argued that it does not go far enough to foster transdisciplinary research to establish deep connections to societal actors.

2.1.12.2. Uptake of R&I results

According to our interviewees, there are several relevant fields where the ACRP cannot deliver, but would, in principle, be well-positioned to do so. These fields have been identified by both our expert interviewees as urgently required to substantially foster the green transition but to be fair, neither exists at the European funding level so far (which has likewise been critiqued). The identification of these required action fields is based on our conversations where there was a frequently repeated premise that there would (rather) not be a further lack of knowledge in the field of climate and climate impact research, but rather of socio-political and economic unwillingness to take unpopular or evidence-driven decisions (from policy-makers down to individuals):

- There are no funding mechanisms in place for improving the precise identification of concrete problems between decision-makers and the scientific community, to which further research should reply to. This void, however, is substantial, since different stakeholder voice their concerns in different terms and jargon, thereby losing precision in posing questions and stating problems to be effectively addressed.

- Climate change, mitigation and adaptation are immensely complex, transdisciplinary challenges, which would require much more participative approaches to knowledge-making, knowledge transfer and policy-making. Eventually, they involve a series of social and particularly ethical questions addressing social, economic and political values and priorities (including fears, hopes and expectations), which are so far however frequently left out (especially if review panels are staffed with scientists from the hard sciences only). It would be required to open up review panels in the field to, for instance, policy experts from other countries, city and municipality administrations and other relevant fields (e. g. arts) to foster knowledge transfer but also citizen engagement and participation more broadly.

- Arguably, research within more participatory structures – e.g., with cities, municipalities and other forms of public administration – does not follow a systematic approach in two ways: First, with regard to the selection of consortium partners, since there are no databases available tracking the most excellence or knowledgeable ones in the field. Selection, therefore, follows other criteria, such as acquaintance or established working relations, yet occasionally ignoring already achieved excellence elsewhere. Second, knowledge obtained through funding remains all too often locked in the drawer, i.e., kept in an internal report or journal article for the scientific community only. This critique is far from new. However, what should be conceived, also within EU research frameworks, would be novel funding mechanisms for ensuring post-project knowledge transfer and exchange across project consortia, as well as, in the case of Horizon Europe, across municipality/city, etc. partners, including the private and public sector.

The words of one of our interlocutors, “Climate research in Austria has enabled us to establish proper structures (strategies, funding, work programmes, etc.), but we still don’t know how to use them properly […]”, are especially significant with regard to the broad relevance and efficiency for ensuring a deep green and structural transition.

2.1.12.3. Networking and infrastructure

The ACRP's unique institutional set-up, its stakeholder dialogue, the fact that there is indeed such a niche research programme in Austria beyond large-scale public funders such as the Austrian Science Fund (FWF), and the frequent inter- and transdisciplinary approach chosen by the funded projects, have all tremendously contributed to community building in Austria, in the area of climate research.

Structurally speaking, though, the ACRP has few cross-programmed links to other activities and funding initiatives even at KLIEN, with the notable exception of the *KLAR!* climate adaptation pillar. Given that the ACRP indeed should or could produce relevant knowledge for more applied and governance-related knowledge – if enabling, or contributing to achieving, the green transition was part of its primary objectives – effectivity seems to underperform to a certain degree when looking at the broader picture (beyond scholarly excellence). It could do more in terms of enabling communities relevant to making the Green Transition goals a reality and (help) creating climate services.

While the community-building within climate research has worked well and while some climate services have started to emerge, their scope and scale are too limited to substantially contribute to a Green Transition in Austria.

2.2. Benchmarking Case 2: FONA – Forschung für Nachhaltigkeit (Research for Sustainability)

2.2.1. Introduction to the international benchmarking case FONA

FONA is under the auspices of the German Ministry of Education and Research (BMBF), more precisely, located with its subdivision 72 (FONA) within its division 7 ("Zukunftsvorsorge - Forschung für Grundlagen und nachhaltige Entwicklung", English: Care for the Future – Elementary Research and Sustainable Development). It emerged as an "out of the pipe" approach in 2005 and has since then continuously been developed into a systemic, interdisciplinary and transdisciplinary sustainability research programme, an objective which was boldly and positively achieved. FONA built upon the earlier Environmental Research and Technology program (1989-1994) aiming at including emission-poor production processes. In addition, in 1998 the "Umweltforschungsprogramm" (environmental research program) of 1997 expanded to include "socio-ecological research", at this time mostly referring to considering the full life cycle of products. Since then, the BMBF established 13 focus points for selected economic sectors, and in parallel also root cause analysis and ecosystem research gained track. Already at this time, the overarching objective has been to gain a better understanding of the complexity between human impact and natural processes, including the global dimension of environment and development.

In 2002, Germany adopted the National Strategy for Sustainable Development, which included 2 main motives: 1 PRONA (action-oriented sustainability concepts) and 2. PROSYS (earth-system analysis and risk assessment), overlooked by subdivision 72 which sought to couple insights for the national strategy and its requirements. Overall societal resilience should be improved in the light of disruptive processes (e.g., climate change) but explicitly addressed also social security, environmentally conscious globalization, societal integration, systemic risks avoided, food security and mega urban agglomerations put up on the agenda. These objectives and themes merged into FONA 1 2005, together with a strong inter and transdisciplinary concern.

According to the 2020 evaluation study, already early on not only were knowledge and innovation generation targeted but global challenges, including multi-stakeholder perspectives, have been addressed in concordance with German aspirations for European and global leadership. Similarly, FONA has additionally always been linked to the national high-tech strategies HTS I to HTS III and HTS 2025.

Institutionally, FONA has been steadily and consciously taken as a tool for not only establishing a proper position division within the BMBF – i.e., which would have enabled sustainability concerns to become a transversal issue across all German RTD activities – thus also aiming at countering the fragmentation into several divisions, referates and, as a side product, thematic silos. FONA should additionally foster research from subdivision 72 (divided into 5 "Referates" or thematic secretariats) and thereby connect the innovation ecosystem of economy, politics and society in novel ways. Today, FONA is still essentially linked to subdivision 72 and contributes to its attempt toward more boldly connecting the innovation ecosystems, in particular since the establishment of the FONA Strategy (by end-2020).

2.2.1.1. Study Constraints

For this benchmarking pilot study, several relevant constraints had to be taken into account. First, due to the national and European internal political contexts at the time of sending interview requests, the German Ministry for Research did not permit conducting interviews with internal policy-makers and further staff concerned in the ministry's subdivision 72 with FONA. Second, an encompassing evaluation study of FONA 3 (2015-2019), which would have been most relevant for direct H2020 comparisons, has neither been mandated (currently in process) nor initiated yet. The only robust available data, however only partially available, for drawing conclusions on FONA 3 performance stems from the 2020 FONA evaluation study mentioned above. Third, FONA entails very limited program monitoring through its Profi-database hosted at the Ministry (point 1 mentioned above entailed that we had no direct access to the database for this study). That is, neither are encompassing statistical data collected on an annual basis nor are any other measures of progress made available publicly. This notwithstanding, the outcomes of the evaluation study 2020 with regard to FONA's overall performance provided us with **concrete entry points for our semi-structured interviews** with members of the evaluation study and top-profile members of the relevant scientific community.

We understand that given our overall theme of green transition and climate change adaptation/mitigation, a **focus on improving social impact through effective communication, differentiated objectives, and targeted instruments** is vital. Therefore, we focused during interviews on the highlighted improvement areas to pinpoint and identify lessons learnt and potential benchmarks for similar funding programmes in Europe.

Guiding questions for the interview of stakeholders as well as a list of interviewees are included in the annexe.

2.2.2. FONA background

FONA is one of the BMBF's main funding programmes, and is deeply committed to the 17 SDGs, the national and European climate targets until 2030, as well as establishing sustainability discourse and action, including change with regard to institutional, governance, teaching/research and higher education landscapes, thus by default going beyond the goals of H2020's R&I scope. The following three key areas have been developed for the organically further developed FONA Strategy (adopted 2020), in itself drawing upon FONA 1 to FONA 3:

- Achieving climate targets
- Protecting, exploring and using Resources and living environments
- Further developing society and economy – fostering well-being in the country

All three areas have assigned 8 thematic action fields respectively, each including 25 concrete actions, which very roughly compare to Work Programmes and different research instruments (CSE, RIA, IA, etc.) in H2020.

Since its beginning, funding and support for research in sustainability has not only been defined thematically but also structurally: across disciplines and including all stakeholders across sectors of society to achieve better systemic understanding. The international impact is important, including cooperation with developing and BRICS-T countries.

Research should be useable in the practice and therefore present useful outcomes; the latter not only in terms of technologies but also as knowledge and behaviour recommendations for political and public planning processes. Moreover, being relevant for societal and technological uptake, i.e., similar to H2020, they should address societal challenges. In particular, five structural properties sought to be fostered: transdisciplinarity, internationalization, transfer orientation and systemic perspectives.

FONA's total funding volume (F1 to F3 or 2005 to 2018) has been 5.198.942.641 €, funding 9773 projects in total. Its overall budget including own costs: 5.851.736.165 €; Own costs amounting to roughly one 1/8th or 0,125% of the overall budget.

2.2.2.1. Legal Basis and Governance

The current legal basis for FONA is the tax and subsidy benefit-related law of 2019 (FZulG; BGBl I S. 2763), which all together form part of the German RTD Guideline, known as High-Tech Strategy 2025 (HTS). FONA's programme owner is the Ministry of Education and Research. However, based on regular public tenders, operations are continuously handed over to executive agencies (*Projektträger*). Executive agencies are responsible for the day-to-day handling of project proposals, reviews, funding administration, etc., but do not have any mandate for project monitoring. While shifting executive agencies constitutes a long-standing regular German practice, problems arise with continuously building up institutional memory and, in particular, implementing a coherent set of monitoring standards.

2.2.3. Thematic Orientation of FONA

FONA is a multi-program initiative, that is, it can be divided thematically and call-related into three periods. However, funding periods, project lifetimes (which could be extended) and outcomes do not necessarily relate to the three overarching FONA periods. The 2020 evaluation divides them in the following way: F1: 2004-2009; F2 2010-2014; F3 2015-2018. In addition, as of 2019, the renamed FONA Strategy is underway. All FONA programmes included funding for the following areas:

- Climate research
- Energy research
- Research on Biodiversity
- Marine and Polar Research

However, every program call put emphases differently. FONA 3, for instance, included three flagship initiatives: Green Economy, City of the Future, and The Energiewende (Germany's transformation of its energy system). In transdisciplinary terms, FONA 3 focused on the following "fields of prevention research" for sustainability:

- Maintaining and enhancing quality of life and competitiveness
- Using resources intelligently and efficiently
- Protecting common assets: climate, biodiversity and the ocean
- Education and research: working together for a sustainable future

In addition, FONA aims at transforming environmental and sustainability education by directly modifying higher education curricula across *Länder* and local administrations. To foster social and not only technological innovation but research and education also went hand in hand. This includes a focus on climate impact research, disaster risk mitigation and adaptation, vulnerability analyses, sector-specific approaches, locally relevant sustainability research on potentials and transformations, etc. While F1 and F2 were essentially geared towards establishing a relevant inter and transdisciplinary scientific community, F3 saw the opening up towards all disciplines and the private sector, including large-scale production companies.

From the vantage point of viewing itself as a European leader in sustainability research, FONA 3 explicitly aimed at close collaboration with H2020's climate action calls and within KICs, such as the one on raw materials and the Climate KIC initiative. These activities should foster the R&I triangle between education, research and industry in "order to transform R&D results into marketable products and services more swiftly and efficiently".[26]

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[26] https://www.fona.de/medien/pdf/pdf_8rch1v/bmbf_fona3_2016_englisch_barrierefrei.pdf, p.30.

A particular focus lies also on marine and polar research collaboration – including the acquisition of the research vessel “Sonne” in 2013/2014 through FONA 2 – e.g., within the European Marine Strategy Framework Directive, but also OSPAR COM and HELCOM.

FONA 3 participated also with the Joint Programming Initiatives (JPI), JPI Water, JPI Climate and JPI Ocean.

While FONA is the largest research programme of its kind in Germany, it is by far not the only one addressing sustainability. Funding programmes located with the Federal Ministry for Economic Affairs and Climate Action address politically much more sensitive strategic sectors with regard to high tech, automotive industries and energy.

2.2.4. FONA Target group and Funding Shares

The programme targets different kinds of research organisations and science-oriented organisations, but also NGOs, public administrations and the private sector more broadly. Research disciplines include, among others, natural sciences, social and economic sciences, legal and technical topics that usually have to be solved in interdisciplinary and, in many cases, also transdisciplinary ways. Additionally, FONA serves to acquire novel research infrastructure (including large-scale) as well as transform existing infrastructures.

Project partners are not limited to German research institutions and can include foreign researchers as well as businesses and other practitioners as long as a full publication of results is guaranteed. Across FONA 1 to 3, research institutions in Germany outside traditional academia have been the biggest beneficiaries in the field of infrastructure, yet in total (projects and proposals), universities have received the most shares (46% of all funding instruments and 36% of proposals funded). External research organizations (e.g., Fraunhofer, Helmholtz Association, Leibniz, Max-Planck, etc.) received 36% of all funding subsidies and 28% of proposals were funded.

However, in terms of overall FONA budget share, external research organizations received 44% (largest share), of which the four largest (mentioned above) allocated 71%. Environmental research organizations without ties to universities and the four largest external institutions outside academia only received 3,8% of the overall funding budget; 1,3% received commissioned research by the BMBF.

2.2.5. Previous evaluations and lessons learnt

FONA has been evaluated at the national level in 2020 (covering a work period of 2018-2020); the accompanying research for FONA 3 has been tendered in 2022. The 2020 evaluation study, most valuable for this benchmarking exercise, is built on a complex set of case studies, a large-scale survey across 8251 FONA-beneficiary project heads (principal investigators, PI) and a Sounding Board. This board included 6 representatives from academia, companies, public administration, and NGOs and has been consulted for individual interviews and workshops. Additionally, 3 focus groups were carried out on 1. Interdisciplinarity, 2. Transdisciplinarity; and 3. Transfer pathways to economy with up to 9 participants each.

The 2020 evaluation underlined positive achievements:

a) FONA effectively helped set up or expand/reorient new research institutions, through which sustainability research has been successfully established. Additionally, this way, career paths were fostered (occasionally over several projects and years).

b) Project and publishing activity has been increasingly transdisciplinary, co-authored with numerous international partners, as well as the establishment of new research directions (e.g., socioecological). This is owed to an in-built preoccupation with global environmental problems, justifying a global role of responsibility for German funding and engagement.

c) FONA targeted and managed to achieve a good number of PhD awards, in addition to funding young career research groups (at an early stage), which added qualification impulses for employment and labour markets.

e) Companies, particularly small and medium, benefitted from FONA with several novel innovation potentials, improved market position, and further qualification of research staff. There were also positive effects according to revenue and employment and internationalization.

f) New forms of evidence-driven public engagement were developed (across citizens, municipalities, and civil society). Municipal administrations were fostered to effectively uptake innovative solutions and ideas.

g) FONAs overall governance structure is very reliable and some leading figures within subdivision 72 have been leading FONA since 2005 or even during its precursory programs.

h) FONA has demonstrated flexibility and community participation to include shifting contexts, to grow and to adapt its portfolio, particularly between FONA 1 and 2, on the one hand, and FONA 3 and 4, on the other.

The same evaluation study finds some serious **caveats** to these outlined successes, and in particular were confirmed through interviews with the lead authors of the study.

For instance, with regard to e), it became clear that in the mid to long run, only larger companies can maintain a sustained benefit from these advances.

With regard to a) and c), young inter and transdisciplinary scholars did not find the same resonance with labour markets (in and outside academia), which means that the lasting establishment of scholarly careers in inter and transdisciplinary research remains an intricate challenge.

Furthermore, is the governance of FONA with regard to g) and h) somewhat hampered by not including proper programme monitoring, and also rudimentarily compiling project (abstract) and outcome data in the Ministry's profile database? According to some interviewees, full project and funding disclosure, transparency and openness on the beneficiaries, etc. would not be in the interest of all parts (including FONA beneficiaries), as well as current legal frameworks.

Representatives from the scientific community also claimed too much weight for non-academic members in FONA's advisory board of experts (in particular after FONA 3).

Generally, the 2020 evaluation study’s main findings listed the following research and societal improvements as recommendations for the next years, without spelling out priorities:

- **Structuration and differentiation of funding instruments:** according to elementary research, applied research and R&D research with a clear marketization perspective.

- **Like the transition from H2020 to Horizon Europe, the adoption of a mission-based approach:** target-operationalization towards societal challenges, cross-sectorial by nature as to FONA acquiring a pioneering role for the BMBF. **Relevant for impactful missions would be** extensive interdependency fine-tuning, ambitious and inspiring but realistic and measurable targets, as well as openness to diverse solution pathways. R&D&I policy needs to become a fundamental part of societal change, including institutional and budgetary changes.

- **Digitalization should be fostered,** especially for fostering research communication and long-term availability of results, not only to foster impact but also with regard to its relevance for sustainability as such.

- **Funding of social innovation from and within civil society, with a particular focus on up-scaling**, including measures for applicants at different career stages and reviewers from outside traditional academic settings.

- **Establishment of experimental spaces:** Living labs for social innovation, bottom-up explorations, research and public administrations should be funded without a targeted marketization interest but long-term perspective (approx. 10 years).

- **Create dedicated databases and platforms for transformative knowledge**, including new taxonomies, providing clear orientation in the light of multiple crises and required disruptive transformations (energy, traffic, food, etc.), but also for the identification of success factors and best practices, as well as the upscaling from niche success to mainstream application. This includes the exit from certain technology, energy and production processes.

- **A necessary institutionalization of research processes-related reflection (including quality criteria) for inter and transdisciplinary research.** This relates to the distinction between the transformative and transdisciplinary role of science, but also to scientific impact and the quality of science more broadly.

- **Transfer perspectives should be explored and expanded from the vantage point of innovation systems.** From the very start, already at the level of designing funding impulses and pillars, economic and juridical dimensions need to be taken into account, and policy-wise addressed when exploring sustainable transformation practices. As an integral part, the innovation context must be considered and funding instruments, seen as "learning programs" continuously be fostered and therefore flexibly adapted.

At the **operational** level, the following recommendations were highlighted:

- **Project teams should receive support means for enhancing transdisciplinarity**, in addition, the criteria for transdisciplinarity should receive more attention in the selection process. Also, transdisciplinary project management tools should be promoted.

- Better **support** for **identifying and selecting project partners** is required, particularly to foster inter and transdisciplinarity. Targeted funding of networks and structures between science and the private/public sector could be one way forward, in addition to massively enhancing science promotion and dissemination.

- The proposal and review process needs clear **definitions** and criteria for (according to differentiated and specific calls) interdisciplinarity, transdisciplinarity, marketization/employability and systemic perspectives. Project selection including **oral presentations**, in addition to on-paper review processes, should be promoted.

- Improving **monitoring** and public disclosure of outcomes

- Consider Strategic use of real-time **secondary assessments**

2.2.6. Relevance

Arguably, according to international policy recommendations (IPCC, EU Green Deal, etc.), the overarching objective of climate and climate impact research is, beyond data collection and periodic updates thereof, to effectively and concretely contribute to the green transition, the achievement of the Sustainable Development Goals (SDGs) and, in the case of Germany, to fulfilling the German Climate Action Program 2030.

In this sense, FONA and its funding pillars are uniquely positioned by combining and working across the public, private, and research sectors. It's clear global outlook of concern contributes to this, with research focuses on the Polar Regions and oceans, but also the developing world.

According to our interviews, and this has been confirmed across all our interviewed stakeholders, in its early years FONA has however had a "branding issue", with rather low levels of recognisability in and outside academia. This had also to do with quite a closed group of researchers and institutions benefitting, in some institutional and departmental cases even "existentially", from FONA funding (FONA 1 and 2). While this has gradually been remedied, it is not a program open to everyone and everywhere from the civil society (having its difficulties in terms of organisation, decision-making, etc.), e.g., NGOs, and the social care sector, with most of its funding going to non-academic (higher) research institutions and in particular to the 4 major non-academic research organizations active at the national level. A trend to centralization and supporting already established scholars, despite attempts otherwise to foster PhD and postdoc scholars, thus cannot be dismissed.

In terms of policy uptake, the FONA evaluation study finds a slight budget allocation (1.3%) to directly mandated research from the BMBF. However, according to our interviews, FONA has not been conceived as a policy advisory program, and therefore the knowledge and information path has not frequently been from research to society and back to policy-making (except at the local, e.g., municipal level). In other words, FONA was less focused on, e.g., delivering results for steering nationally relevant climate policies in new directions, rather than inciting and impacting society, higher education and private sectors to implement interdisciplinarily relevant knowledge and discourses with regard to sustainability and climate change mitigation/adaption (as of FONA 3 and 4).

There is also another dimension of unmet relevance which needs to be discussed: while FONA has effectively managed to establish and foster a relevant scientific community, there is a gap perceived by interviewed experts with regard to better implementation and embedding of FONA perspectives and outcomes as a cross-cutting issue between larger national international funding programmes. On the other hand, FONA has provided for instance tsunami warning systems to Indonesia, contributes to ocean science through the SONNE vessel, etc. at the global level, thus evidencing a clear understanding of climate change as something of global concern. Several of our interlocutors confirmed that international partnerships within FONA-funded projects were expanding over time. This can be corroborated by bibliometric findings: A share of 80% of H2020 publications were international co-publications, against 58% for FONA publications by selected German authors (notwithstanding the methodological difficulties of such comparison). The increase over time in international co-publication was driven primarily by increased collaboration with Associated countries. The share of publications with a least one participation by a researcher from an Associated Country went from 8% in FONA publications to 27% in H2020 publications for selected German authors. The average share of authorship for authors from Associated countries has gone from 1% to 5%. Participation by researchers from RIS countries has also increased for German researchers when comparing their H2020-funded papers against FONA-funded ones.

This certainly reflects diverging policy priorities and interests between the European and national funding levels. FONA understands itself as the leading European sustainability framework programme, in this sense facilitating comparisons with H2020 and Horizon Europe, at least with regard to the German research landscape. Also, within universities, large-scale EU-funded research, with an extremely competitive positive approval rate, is highly resource-binding during the proposal preparation phase and thus frequently perceived as unnecessarily binding staff and resources with highly uncertain outcomes. To some extent, FONA can do better at the local and national level, especially if it includes novel research (e.g., reflexive and exploratory) spaces as highlighted in the 2020 evolution's recommendations.

In the sense of bringing about a green transition and taking into account societal and policy relevance as the necessary fields for generating lasting change, we argue that the EU FPs, but also other member states, could learn quite a lot from the German long-standing efforts in the field. Vice versa, Horizon Europe with its already implemented mission-based and society challenges-focused approach could provide a blueprint for further developing FONA 4 (and perhaps beyond) in the future. Additionally, efforts to harmonize and align national and European funding (through partnerships, JPIs, etc.) should be fostered even further. In all cases, this would involve a much better, public transparent monitoring and knowledge-transfer mechanism for FONA, for instance, to achieve full socio-political relevance and thus increase media attention.

2.2.7. Effectiveness

Sustainability research (FONA 1 and 2) and sustainability transformation research funding (esp. FONA 3 and 4) by subdivision 72 was an effective way to reach the goals that FONA FP strived to accomplish. There is impact on multiple levels: internationally, nationally, regionally, and locally. This can be exemplified by FONA action contributions to the IPCC and COPs at the international level, the FONA action on a national level and research on climate impact adaptation (e.g., droughts, floodings, etc.) on a regional or local ecosystem level.

The focus of the framework program, now strategy (FONA 4), is to provide various instruments for placing sustainability talk and actions on the national and institutional agenda, including the private sector. It does not limit itself to the national context but includes a global outlook, while focusing on systemic institutional, capacity and knowledge transformation at the national level. Inter- and transdisciplinary vulnerability studies, risk management approaches and, to a lesser extent, policy analysis are key actions in this undertaking.

Cross-disciplinarity

With regard to the 2020 evaluation assessment of FONA, our bibliometric analysis comparing German H2020-funded publications with FONA-funded ones finds important nuances: Considering only the capacity of each funder to foster large shares of highly multidisciplinary publications within sets of supported articles (DDA10%), a statistically robust gap was found for H2020 funding as compared to FONA funding. H2020-supported publications by selected German authors were 20% more likely to be highly multidisciplinary (1.2) than expected, against 70% more likely than expected (1.7) for FONA-supported papers. However, when looking at interdisciplinarity, according to Science Metrix data, H2020 and FONA-funded publications performed similarly in both tests or with inconclusive, small differences (DDR of 0.7 to 0.8 in the main test, although statistically inconclusive).

Academic-private co-publication

What additionally seems to have achieved rather little output impact is the stated relevant FONA focus on including and financing non-academic research and private sector research: A share of 13% of H2020 publications by selected German authors included both academic and private firm authors, against 4% for FONA publications. The value-added of H2020 funding on this dimension was statistically definitive at +9.4 percentage points. It can be noted that H2020-funded publications generally saw more academic-private co-publications (16%) than FONA-funded publications (6%), reinforcing the conclusion that H2020-funding has been more effective at fostering academic-private co-publication than FONA funding.

Beyond academic publication output, it is however notable that, according to our expert interviews, FONA I and FONA II actions produced many reports and other text output that contributed to policy-making but also mainstreaming sustainability research and transformation in Germany. Regarding this point, preliminary bibliometric data, however preliminary, supports FONA effectivity when compared to H2020: The normalized share of publications by selected German authors cited in policy-related documents was twelve times the expected for both their H2020 and FONA publications. H2020 funding did not so far enable differential gains on this dimension against FONA funding.[27]

Overall, FONA 1 (still limited to establishing funding and networking bases for socio-ecologically like-minded scholars in the climate research field) and FONA 2 effectively managed to expand and reorient both in the academic and private sectors (particularly with FONA 3). Companies, especially SMEs, benefitted from FONA with a lot of innovation potential, improved market position, and qualification of research staff. According to the 2020 evaluation report, there are also positive effects according to revenue and employment and internationalization. However, according to some of our interviews, and despite a higher effectiveness curve for SMEs during FONA-supported actions, only larger companies were able to maintain a sustained benefit from these advances once finalised FONA-specific support.

Gender equality in publication authorship

In this regard, H2020 publications by selected German researchers included at least one female author in 89% of cases, against 76% of FONA publications, resulting in a clear signal of differential effectiveness for H2020 funding in the controlled analysis. The clear signal just described was not retrieved in the overall H2020 and FONA publication sets, however. Authorships on H2020 publications were taken up by women in 31% of cases on average, against 31% of cases for FONA publications. H2020's differential gap is significant here at -5.6 percentage points. Again, the signal from the controlled analysis is not repeated in the overall publication sets for average shares of authorship taken up by women. Both H2020 and FONA publications recorded averages of 30% of authorship taken up by women.

In the public domain, new forms of engagement were developed, and municipal administrations were provided with evidence-based data to effectively uptake innovative solutions and ideas. This has been the case thanks to the high applicability of FONA-funded research. However, transdisciplinary

[27] It should be noted that mentions of journal publications in policy-related documents are optimally computed using citation windows of 4 years, which have not been elapsed in the available. Therefore, these findings are preliminary and subject to change.

research and outcome require a higher level of coordination and communication tasks, which also affects the way transition action support needs to be conceived in terms of efficiency.

Propensity to open-access publishing

A proportion of 95% of H2020 publications by selected German researchers was available under an OA modality, against 91% of FONA publications. H2020's slight lead was not statistically robust, meaning it would be safer to assume that H2020 and FONA funding have both fostered comparable levels of OA publishing.

2.2.8. Efficiency

Overall, project administration and proposal management of FONA has been esteemed as highly transparent, professional and efficient. FONA has existed for over 20 years and is a large framework programme with extensive experience in funding research, which has resulted in continuously optimised and standardised processes. The supporting IT systems, except refined tools for project monitoring, are generally well-developed, but access to the "Profi database" requires specific authorization from the Ministry, not accessible to the general public (unlike CORDIS). As they are integrated into the streamlined project application, selection and funding allocation processes, they work as they are expected to deliver.

In terms of the actual application process for proposals including the merit review criteria which are all clear and well-explained in the documentation. However, it should be noted that interviewees mentioned that a program USP and ownership problem persisted throughout FONA 1 and 2, in the sense that it was not always clear to everyone involved in the projects that FONA has been the main funding source for institutional and research activities. This improved over time, as well as more explicitly addressing civil society organizations and policy-makers, clearly demonstrating flexibility and learning effects from programme to programme.

As mentioned above, transdisciplinary research – effectively required to bring about a green transition at all societal levels – comes with certain strings attached. These refer, on the one hand, to increased coordination and communication demands, which bloat project management and tend to expand project cycles substantially, especially when including stakeholders from outside traditional research. In the case of FONA, awareness about this growing gap has been created but still awaits a coordinated response – according to our expert interviewees from the academic research community.

In addition, scaling up knowledge and network creation through mutual learning exercises and twinning projects was hampered to some degree (in FONA 1 and 2) by not (much) including NGOs and other social and environmental civil society organisations, or civil society more broadly. To bring about more disruptive and radical solutions to the triple crisis (nature, biodiversity, climate change impact), this would be necessary.

However, a structural and historically grown institutional organization in the field of higher research and education is lacking behind these demands: academic career paths follow still predominantly a single or dual-disciplinary approach, and the same holds for education as well, where multidisciplinary and interdisciplinary focuses have increased. Yet, there is still leeway to fully incorporate transdisciplinary research in its broad sense of co-design, co-creation and two-way knowledge transfer.

FONA 3 aimed at addressing some of these shortcomings by providing additional action to academic institutional transition, yet it struggled to ensure further employability and continue scholars' careers (and institutes) beyond FONA funding.

With regard to H2020, there might be some similarities if we look at broad cross-cutting calls and related research actions. With regard to Horizon Europe, there is a risk of establishing some sort of "European inter and transdisciplinary research community" which might struggle to obtain relevant posts and research funding beyond the European FPs.

These critical remarks notwithstanding, FONA 1-3 effectively managed to, which was confirmed across all interviewed sector representatives, deliver what it was supposed to deliver. That is, an **interdisciplinary research community**, an **international outlook with a claim to European and world leadership in the field of climate change adaptation**, with successful ties to the private and public sector (especially at the regional and municipal level); and eventually also **sustainability-related impact within academic research structures**, including addressing **direct institutional transformation** (both within universities and non-academic research institutions) with dedicated funding instruments (in this sense going beyond EU FP's typically indirect approach).

2.2.9. Outcome dimensions

2.2.9.1. Strategic development

In terms of strategic development, the key question is whether the programme kept abreast with and adapted to changing or emerging global and national situations, such as the Paris Climate Accords or the Green Deal. In this regard, FONA fares quite well according to our interviewees – it has intended to provide scientific background for the implementation of the German Climate Action Programme 2030, the European Green Deal, the 17 SDGs, and the Paris Agreement in Germany. In particular, the shift from FONA 2 to FONA 3 towards a more encompassing national research programme, re-potentiated with FONA 4 (FONA Strategy) evidences this strategic reasoning and purpose. There are however critical voices, which pointed out the persistent lack of civil society and NGO engagement, which with FONA 3 was addressed, and should have been fully integrated with FONA 4 seems to have been improved (yet evaluation results are missing).

While efforts towards the Green Transition have not been scaled up – in relative terms – by the FONA as they have within H2020 (through the Green Deal), the former has indeed reacted to the shifting policy landscape. Although FONA highly stimulates interdisciplinary research, it could be argued that it does not go far enough to foster lasting and sustainable transdisciplinary research to establish deep connections to societal actors.

2.2.9.2. Uptake of R&I results

Within the FONA-operating ministry, uptake has continuously occurred since FONA 1, however concrete data on this process is scarce. In our study it has been pointed out (as of yet) missed transformation of subdivision 72 into a cross-sectoral secretariat or similar, which would have meant making sustainability an overarching issue for all Ministry actions and programs.

However, FONA results and actions were taken up by the academic and private sectors. The 2020 evaluation dedicated a case study to SME's take-ups which seemed very positive, but also evidences certain challenges with prolonged follow-up engagement after the funding expires due to economic barriers.

Identification of concrete action fields for the FONA program is mostly an internal process within the ministry, some detachment to other societal sectors cannot be dismissed: While FONA has occasionally included funding of explorative research, there are very few funding instruments in place for improving the precise identification of concrete problems between decision-makers, civil society and the scientific community, to which further research should reply to. In addition, FONA is today much more geared towards socio-ecological research for technological and economic applicability than it used to be in the beginning. So-called "synthetizing" social science approaches, focused on stakeholder mapping, decision-making support, and making governance processes more inclusive and effective, have been a rather weak point throughout all FONA programmes.

Regarding corroborating data on patent citation uptake (which are very preliminary and subject to change), it was found that H2020 publications by selected German authors have already received citations from patents (10% less than expected at 0.9), whereas FONA publications by the same authors have not. It should be noted that mentions of journal publications in patents are optimally computed using citation windows of 7 years, which have not elapsed here.

In more statistically robust terms, H2020 publications by selected German authors mentioned at least once in online journalistic coverage, was six times the expected level, against three times the expected level for the share of FONA publications by the same authors. The lead by H2020 publications on this dimension was statistically robust, and the comparison of the baselines also reinforced this finding. The share of H2020 publications mentioned at least once in a Facebook post was three times the expected level, against 50% above the expected level for FONA publications by the same authors. Again, the H2020 lead was statistically robust here, although the external validity of these findings may be somewhat limited as shown by the two baseline findings.

2.2.9.3. Networking and infrastructure

In terms of network, FONA 1 and 2 have undoubtedly played a vital role in establishing not only research and outreach actions but also institutional change at the national and regional levels, particularly within academia. For instance, the renowned IASS (Institute for Transformative Sustainability Research) in Potsdam has received funding through FONA from early on.

While FONA 1 and 2 focused on an emerging socio-ecologically minded interdisciplinary research network, FONA 3 (and in the context of political changes at the ministerial level) opted for more pro-growth and pro-industry engagement, effectively broadening FONA's scope and instruments. FONA 4 turned into a national strategy, with as of yet unclear results.

In terms of infrastructure for transformative sustainability engagement, FONA contributed from the beginning by enabling the updating and acquisition of the required and appropriate large-scale equipment for universities and research institutions outside academia through public procurement which would have not been possible otherwise (e.g., research vessel "Sonne" in FONA 2).

Internal (institutional and governmental) policy uptake of FONA results could have contributed more to setting the agenda across ministries, though, especially with regard to impacting, e.g., with sustainability criteria, the research actions and funding by the concerned ministries for high-tech and industries. This, however, would be linked to broader public engagement, political participation, fostered dissemination as well as programme monitoring – that is, in all fields where FONA 1-3 has been regarded as having high potential but with an average performance.

2.2.9.4. Transdisciplinarity

In terms of transdisciplinarity, FONA 1 and 2 clearly lagged by focusing on interdisciplinarity by default, i.e., not having a broader engagement in its scope. Also, FONA 3 only partly and in certain actions – by including the private sector – managed to incorporate both policy-making and civil society more broadly (and certainly more than comparable other framework programmes in Germany). For this reason, in the following, we present some overall comparison results regarding the benchmarking of FONA against H2020, which corroborate this statement:

- H2020 publication performances for selected German authors led to FONA achievements on the dimensions of 1) share of highly interdisciplinary publications 2) share of academic-private co-publications; and 3) balanced citation impact as captured by the CDI 4) Field-weighted CiteScore (journal-level citation impact) 5) altmetrics mentions in online journalistic coverage 6) altmetrics mentions on Facebook posts.

- H2020 publication performances for selected German authors led to FONA achievements, but potentially with limited external validity, on the dimensions of 1) share of publications written as international co-publications 2) average number of distinct countries of affiliation per publication 3) Shares of publication with authorship contributions from at least one woman researcher (although this achievement did not carry over to average publication-level share of authorships by women).

- Both H2020 publications and FONA publications recorded comparable scores on 1) average multidisciplinarity and average interdisciplinarity 2) share of publications available in OA 3) uptake in policy-related literature 4) Twitter and Wikipedia mentions.

FONA publications by selected German researchers performed better than H2020 publications by the same researchers on 1) shares of highly multidisciplinary publications.

2.2.10. Conclusions

2.2.10.1. Efficiency

In terms of efficiency, the FONA framework programme fares relatively well: given its scope and learning curve, it managed to process an increasingly large number of projects quite efficiently and even managed to grow and expand over several years, e. g. with regard to launching the new FONA Strategy as encompassing funding mechanism. Furthermore, certain solutions to the persistent criticism of different stakeholders to structural problems were found, e.g., the lack of a proper monitoring system or the missing digitalization strategy. However, project review and selection function, according to all experts interviewed, to an extremely professional and transparent level, as well as the overall portfolio administration. Since there are structural limits in terms of the validity and robustness of bibliometric data, several statistical comparisons on the outcome efficiency need to be considered carefully. In addition, at least FONA 1 and parts of FONA 2 focused on producing different outcomes (e.g., conferences, working papers, reports, discussion inputs, policy briefs, etc.) than high-impact scholarly journal articles. Overall, FONA's efficiency can be assessed as very high.

2.2.10.2. Effectiveness

Overall, for the assessed period (excluding FONA 4; and FONA 3 partly) the collected evidence shows that the broad field of sustainability research and actions (including climate) that is funded through FONA is an effective means to accomplish the FONA objectives. FONA plays an essential role in research, knowledge, capacity-making and institutional transformation that is conducted on multiple levels, ranging from international to local research. FONA objectives had therefore to adapt and expand over the years, evidencing a high level of flexibility and responsiveness to changed societal and political contexts.

With regards to the impact of the research that was funded by FONA, German H2020 publications tend to achieve a stronger citation impact profile, as well as scoring well on other indicators such as policy uptake, patents, communication, and dissemination activities, but numbers for German FONA publications are certainly high and way above world levels.

2.2.11. FONA Interviews and list of interviewees

During June and July 2022, we conducted a series of 5 semi-structured online interviews with FONA evaluators and scientific community members who have also been acting on the FONA, Sounding Board. Each interview took roughly 45 to 90 minutes and followed a set of guiding questions for the different scenarios comprising public and private interlocutors. Our questions generally followed the idea of having our interviewees themselves assess FONA's strength and success stories, in addition to its overall efficiency, effectiveness, and relevance.

We also aimed at capturing those socio-political obstacles which prevent the deeper structural changes necessary to bring about the "green transition", and the role of publicly funded science in this process. Strategies for better knowledge generation and thus public policy input were collected from our interviewees.

All interviews were recorded, transcribed, and qualitatively analysed. The overall response rate was very positive, taking into account the extreme time pressure of this pilot study; some interviewees preferred to remain anonymous with regard to their answers to our study.

2.2.11.1. Table: List of FONA-related interviewees

Senior Expert	Lead FONA evaluator PROGNOS
Senior Expert	FONA evaluator PROGNOS
Lead evaluator	Fraunhofer ISI
Professor	Scientific Director, IASS Potsdam
Senior Expert	Fraunhofer ISI

2.3. Benchmarking Case 3: KLIMAFORSK – Norwegian climate research programme

2.3.1. Introduction to the international benchmarking case KLIMAFORSK

In 2013, the RCN (Research Council of Norway) established the Large-scale programme KLIMAFORSK to foster excellent climate research and build the bridge between climate science, public policy and society. KLIMAFORSK succeeded NORKLIMA, the initial Large-scale programme focused on climate research. In 2019, KLIMAFORSK was integrated into the Climate- and polar research portfolio of the RCN, as the RCN changed from large-scale programme management to active portfolio management.

KLIMAFORSK was one of several RCN programmes funding fundamental climate research in Norway. As explained, KLIMAFORSK's activities are now integrated into RCN's Climate- and polar research portfolio. KLIMAFORSK is mainly financed by the Ministry of Climate and Environment and the Ministry of Education and Research. Previously, the Ministry of Agriculture and Food (until 2016), and the Ministry of Trade and Industry (until 2018) also partially funded KLIMAFORSK. KLIMAFORSK has been managed by RCN as executive agency since its inception in 2013 as the successor of NORKLIMA which itself dated back to 2004.

2.3.2. Thematic orientation of KLIMAFORSK

The objective of KLIMAFORSK was to promote excellent climate research and foster the translation to other parts of society, such as public policy and the general public. To achieve this, three scientific objectives formed the basis of KLIMAFORSK. Specifically, the programme aimed to increase knowledge about the following topics:

- Natural and anthropogenic climate change (SO1)
- The impacts of climate change on nature and society (SO2)
- The transition to a low-emission society and adaptation to climate change (SO3)

A clear emphasis can be seen on both the scientific side as well as the need to integrate the social side in order to support the societal adaptation to climate change.

2.3.2.1. Study Constraints

For this benchmarking pilot study, several constraints were to be taken into account. Aside from KLIMAFORSK's evaluation report, relatively few sources of information were available. It should be noted that the evaluation report did provide sufficient information. In addition to that, while the people who contributed to the study were of much help and a broad range of stakeholders have been interviewed, there were some difficulties in arranging an adequate number of interviews. Among the reasons that were mentioned were their availability and the timing of the interviewing period.

Overall, the data available are considered sufficient for purpose of analysis. Guiding questions for the interview of stakeholders as well as a list of interviewees are included in the annexe. In addition, we conducted an in-depth analysis of the material and (rather rudimentary) research project database available online.

2.3.3. *KLIMAFORSK target group*

Since KLIMAFORSK was a large-scale programme, its scope included different types of academic research, ranging from fundamental research to applied research. The target group of KLIMAFORSK consists therefore of a broad range of scientists, stemming from ocean or terrestrial research to humanities and social sciences.

2.3.4. Legal basis and governance

The programme harkens back to its predecessor NORKLIMA, the first of the so-called Large-scale Programmes created in 2004. In 2012, RCN evaluated the Norwegian climate research.[28] This evaluation pointed out that Norwegian research on climate was of excellent quality and that Norwegian research groups contributed to national and international research, but that an overarching focus was lacking, and most research groups acted individually. Therefore, the evaluation recommended establishing an overarching large-scale programme that also included the humanities and social sciences aspect. Furthermore, the document *The knowledge base for a new climate initiative in the Research Council*[29] combined the results of other preparatory work that was done for the establishment of KLIMAFORSK, a committee was set up to draft the work programme and finally, a public consultation was held.

Both the KLIMAFORKS *Programme Board* and the *Programme administration* performed tasks that supported the strategic actions and day-to-day activities of KLIMAFORSK. The *Programme Board* was

[28] Research Council Norway, 2012, Norwegian climate research: an evaluation.
[29] Kunnskapsgrunnlag for en ny klimasatsing i Forskningsrådet 2012

responsible for the strategic priorities and instruments for achieving KLIMAFORSK's objectives. The Programme Board 2013-2019 consisted of ten members from universities, institutes, industry, and government agencies in Scandinavia. The *Programme administration* was responsible for operations and administrative follow-up of projects under the programme. The programme administration consisted of a programme coordinator assisted by personnel with scientific and administrative expertise.

2.3.5. Instruments

KLIMAFORSK is mainly based on calls for proposal. KLIMAFORSK was responsible for or participated in 45 calls. In total 15 out of the 45 calls were in collaboration with other Large-scale programmes (e.g., MARINFORSK, MILJØFORSK, and POLARPROG). In addition to that, KLIMAFORSK contributed with 7 out of the 45 calls to international collaborative calls (e.g., Belmont Forum and JPI Climate).

Based on the three thematic scientific objectives, KLIMAFORSK implemented a three year-cycle of annual KLIMAFORSK calls. On a rolling basis, the main annual call had the focus on either 1. Climate Systems (SO1); 2. Impacts (SO2); or 3. Transition (SO3). The main aim of this setup is to create consistency for relevant research groups.

Aside from the main annual thematic call, research groups also could apply for the so-called 'Free Climate Research' (FRIKLIM) calls, which occurred three times (in 2014, 2016 and 2019). FRIKLIM calls are not linked to thematic specificities but need to achieve high-quality research that is both bold and innovative.

During the period 2014-2020, KLIMAFORSK allocated ~ 1,369 bn NOK (~ 140 m €) to 296 projects. Seven different project types exist to cover a wide range of objectives. KLIMAFORSK's main project type is the *Researcher Project*, which is aimed to contribute to important new insights, scientific publication, researcher training and international research collaboration. In total 132 funded projects belong to the category *of Researcher Project*. There were in total 22 FRIKLIM *Researcher Projects*, which also received additional funds from other RCN budgets in 2014 (to strengthen excellent projects) and 2019 (to strengthen excellent projects and humanities.

The other instruments are *Collaborative Projects* (i.e., researcher projects with user participation), *Communication and dissemination* projects, *Guest Research Scholarship*, *Scholarship for research stays abroad*, *Support for events*, and *other projects*. The mix of different types of ways that the programme can select projects to fund creates a unique mix of a top-down thematic perspective and a bottom-up open approach.

2.3.6. KLIMAFORSK objectives

The KLIMAFORSK work programme states as its primary objective the promotion of outstanding climate research and the generation of essential knowledge about the climate for the benefit of society.

As previously mentioned, this objective is operationalised along three scientific objectives:

- Natural and anthropogenic climate change (SO1)
  - Observations and process understanding
  - Climate variability and change
  - Modelling climate evolution at the global and national level.
- The impacts of climate change on nature and society (SO2)
  - Impacts of climate change on the physical and chemical environment
  - Impacts of climate change on ecosystems
  - Interactions between drivers and feedback effects on the climate system
  - The consequences of climate change for infrastructure, trade and industry and living conditions.
- The transition to a low-emission society and adaptation to climate change (SO3)

- Questions relating to both mitigation and adaptation
- Questions relating to reducing GHG emissions and increasing carbon sequestration
- Questions relating to adaptation
- Questions relating to interactions between mitigation and adaptation

- However, in addition to the scientific objectives, KLIMAFORSK was also set up to contribute to broader non-research-related objectives, the so-called structural objectives. There were seven structural objectives:

- Promote cooperation and task distribution in climate research
- Encourage boldness in scientific thinking and scientific innovation in research projects
- Enhance the international profile and contribution of Norwegian research groups
- Foster the development of a new generation of climate researchers
- Expand expertise and applicable knowledge in society
- Facilitate targeted communication and dissemination activities
- Increase the use of available data and research infrastructure

2.3.7. Previous evaluations and lessons learnt

KLIMAFORSK was evaluated during the period 2020-2021. The main goal of the evaluation was to gather information on the achievements and lessons learnt from KLIMAFORSK. Based on the evaluation, valuable input could be provided for the newly established Climate- and polar research portfolio and recommendations could be developed for the development of future climate research priorities.

The most important conclusion from the Evaluation Committee is that KLIMAFORSK realised its main objective of promoting outstanding climate research and providing knowledge about the connection between climate (research) and the benefits for society. As a result of KLIMAFORSK, researchers were able to better understand climate (change) and the potential societal effects caused by climate change. According to the Evaluation Committee, the majority of the objectives have been achieved. This was driven mainly by the annual call with changing themes, the FRIKLIM calls, the contributions to joint national and international calls, and research infrastructures. Both the predictability of the already announced themes of the annual calls as well as the FRIKLIM calls were mentioned by multiple interviewees as very important components of the success of KLIMAFORSK. In terms of impact, it should be noted that most of the research results are of high quality but also incremental.

Regarding the need, identified by the 2012 evaluation of Norwegian climate research, to unite the Norwegian climate research groups, the Evaluation Committee concludes that KLIMAFORSK activities are sufficiently coordinated. Concerning the contributions of individual research activities, the Committee mentions that these are rather incremental and that outstanding scientific achievements are exceptional. Yet, KLIMAFORSK and the research groups have been vital in building and maintaining Norway's status as a leading country in climate research, which is exemplified by the strong contributions to IPCC and other international fora.

2.3.7.1. Recommendations from the 2021 evaluation

Following the evaluation, the Evaluation Committee has formulated several recommendations that should be considered for the implementation of the Climate- and polar research portfolio and future climate research policy. The recommendations are structured along three lines: research themes and focus areas; implementation and programming; and indicators, monitoring, and evaluation. The Committee does not prioritise recommendations, however, two recommendations stand out.

First of all, as KLIMAFORSK's work programme was developed before the launch of the 2030 Agenda and the 17 Sustainable Development Goals (SDGs), it is important that these should be integrated into the research programmes and/or portfolios. Second, the Evaluation Committee mentions that outstanding research often is caused by interactions between different scientific disciplines and sectors. It is, therefore, recommended that inter- and transdisciplinary research takes a prominent place in future climate research.

2.3.8. KLIMAFORSK benchmarking results

The foundation of KLIMAFORSK was based on an evaluation of the Norwegian climate research as commissioned by the RCN. While the research stemming from Norwegian climate research groups was of excellent quality, the evaluators pointed out that an all-encompassing focus in the Norwegian climate research landscape was missing. In this spirit, the objective of KLIMAFORSK also touches upon these two points, namely, to support excellent research and promote the translation of this research to society.

Both the 2021 evaluation as well as interviewees point out that generally speaking KLIMAFORSK has achieved the overarching objectives. The interviewees agree that KLIMAFORSK was an important and successful programme. One of the important reasons for the success is the operational set-up of KLIMAFORSK. In general, the KLIMAFORSK programme board was responsible for setting up the strategy for KLIMAFORSK. On an annual basis, the overall direction of KLIMAFORSK (i.e., strategic priorities, research needs, etc,) was assessed by the Board. This process was driven by annual research needs that were compiled by the funding Ministries and discussed with the Programme Board. This process was operationalised through both the recurring calls system and an open call system. The recurring calls were centred along the three thematic priorities. On a rolling basis, one of the three topics is chosen as the subject for the annual call. Aside from that, the so-called free calls (i.e., FRIKLIM) also existed, where researchers were free to submit calls related to one of the three topics without a specific predetermined topic. According to our interviewees, this set-up provided clarity for the researchers, which was regarded positive part of the programme. By knowing what is coming, research groups can build long-term planning as they are aware of when they can apply for funding.

In terms of the topics themselves, the three topics (and sub-topics) include the full spectrum of climate research. The topic *Natural and anthropogenic climate change* is vital to understanding climate change at both the national level and global levels. By observing the climate over a longer period and modelling the evolution accordingly, researchers provide the basis for any other climate-related research. However, as climate change already is changing nature and has its impact on society, the other topics also cover the actual effects of climate change on nature and society and measures to adapt to climate change. Interviews confirmed the good coverage of climate change-related research topics. With regards to FRIKLIM, while on the one hand, there is no doubt that the existence of the free calls is positive as it by definition funds out-of-the-box proposals, some interviewees mentioned that more innovative projects could have been funded through this call. On the one hand, it is more difficult to assess these calls as compared to regular calls, as they usually are covering more disciplines and are riskier which makes the calls more difficult to assess. However, on the other hand, often these projects are bolder and can potentially lead to relatively more impact.

In terms of impact, the projects that fall under the first topic – climate modelling – are regarded as instrumental to the Norwegian and global climate modelling community. Researchers and research groups are well-integrated into the global community as is exemplified by their contributions to the IPCC. Through these prominent positions, Norwegian researchers influence the national and international debate. As previously mentioned, the research results were of high-quality, but also incremental. This was also echoed by interviewees. KLIMAFORSK, the RCN and the relevant ministries also annually discussed the research needs for the coming years. In combination with the representatives of the different stakeholder communities in the programme board, the research priorities of KLIMAFORSK always stayed relevant for multiple stakeholders and not only for science.

However, there were difficulties to find the balance between fundamental research and more applied research, which tries to solve the problems or come up with adaptation measures. This is also linked to the difficulties with integrating humanities and social sciences into the calls and/or projects. While the evaluation of KLIMAFORSK concludes that the number of projects that include humanities and social sciences is rather big, it was mentioned by several interviewees that in their opinion, the number of projects including humanities and social sciences was not sufficient. According to these interviewees, in this perspective, KLIMAFORSK was lagging behind Horizon 2020 in tackling this issue. Nevertheless, in the Climate- and polar research portfolio that has replaced the research programme a strong focus is placed on integrating humanities and social sciences.

The same explanation holds for inter- and transdisciplinary research supported by KLIMAFORSK. While the evaluation considers KLIMAFORSK's efforts to promote inter- and transdisciplinary research to be satisfactory, several interviewees mention that this is very important, especially in the context of climate (change) research. Through the FRIKLIM calls (i.e., the open calls), these inter- and transdisciplinary projects were supported as it specifically was set up to fund high-quality projects that are bold in their scientific approach and innovative. Indeed, calls that are structured this way provide the highest potential to fund projects that are potentially very impactful (in scientific, societal or economic terms). The objective of these FRIKLIM projects was achieved, however, interviewees mentioned that those deciding which calls are funded could have allocated more funding to these special calls.

With regards to the funding of KLIMAFORSK, as previously mentioned, it was mainly funded by the Ministry of Climate and Environment and the Ministry of Education and Research. Furthermore, there was additional funding from the Ministry of Agriculture and Food and the Ministry of Trade, Industry and Fisheries (from respectively 2014-2015, and 2014-2018), however, these amounts were relatively little. Funding coming from the Ministry of Climate and Environment increased over the years, whereas funding coming from the Ministry of Education and Research decreased over the years. Generally, the total annual funding remained the same over the years (ca. 150 NOK Million or 15 Million EUR). According to interviewees, however, there was an expectation following the introduction of KLIMAFORSK that over the years the funding would rise, which had not happened. Other interviewees mentioned that this type of research has been low on the priority list and therefore KLIMAFORSK had to deal with relatively smaller budgets as compared to other research programmes. However, it was also noted that more and more topics that are covered by KLIMAFORSK's scope are becoming more important as the priority to research climate change becomes higher (e.g., international developments such as SDGs and EU Green Deal).

Finally, an important part of the research process is the communication and dissemination efforts of the research activities. The facilitation of these activities was included as a structural objective of KLIMAFORSK. Projects funded by KLIMAFORSK are required to engage in communication efforts to foster dialogue between different stakeholders. There was also a targeted call for communication projects, specifically to inform the general public. The evaluation concluded that KLIMAFORSK was generally successful in facilitating the communication and dissemination of research outcomes. This was the most successful for the research community, but reaching the general public is more difficult. As was mentioned by one of the interviewees, to reach society at large one should be creative and not only write a short piece on the research.

2.3.8.1. Quantitative benchmarking of KLIMAFORSK

The following quantitative benchmark of KLIMAFORSK was prepared by Science-Metrix. It compares KLIMAFORSK and H2020 with each other and to world averages from several perspectives: International co-publication output; cross-disciplinary research; science-industry co-publications; science-industry co-publications; citation impact; gender equality in authorships; open access; policy-related uptake; and indicators beyond academia.

International co-publication output[30]

On most international co-publication indicators, KLIMAFORSK is lagging behind Horizon 2020. However, considering the scope and size of KLIMAFORSK, this was expected.

A share of 87% of H2020 publications were international co-publications, against 69% for KLIMAFORSK publications. The differential increase brought about by H2020-funding is therefore close to 19 percentage points.

49% of H2020 publications were written by at least one EU27 researcher as either first, last or corresponding author, against 20% in KLIMAFORSK publications. Again, this differential increase is fully expected given the status of Norway as Associated Country. The share of publications rises to 63% when considering the EU27+UK aggregate, capturing the many collaboration linkages between Norway and the UK.

[30] It should be kept in mind that Norway is an Associated Country that falls within the ERA aggregate but not the EU27 aggregate. Any participation in H2020 projects or publications, therefore, increases its share of co-publications with EU27 researchers by definition.

A proportion of 14% of H2020 publications were international co-publications with contributions from an author from a RIS country as either the first, last or corresponding author. This share was 3% for KLIMAFORSK papers.[31]

Findings on collaborations with researchers from other Associated Countries are statistically inconclusive. This finding also complicates the interpretation of findings on collaboration with ERA-based researchers.

A proportion of 35% of H2020 publications were international co-publications with contributions from an author from a Third Country as either the first, last or corresponding author. This share was 29% for KLIMAFORSK papers, but the differential increase brought about by H2020 funding was not statistically definitive. The differential increase in the share of authorships from third countries was statistically robust, however, at +5 percentage points (from 18% in KLIMAFORSK publications to 23% in H2020 publications).

The average number of unique countries per publication in H2020 publications was always above the corresponding figures found in KLIMAFORSK publications, at statistically robust levels.

While differential increases in unique EU27 countries involved in international co-publications were expected, H2020 publications by Norwegian researchers also saw increases in the average number of involvement by other Associated Countries (from 1.4 to 1.8 per paper) and Third Countries (from 1.0 to 1.9 Third Countries involved on average per paper).

The combination of these observations is that H2020 publications by Norwegian researchers recorded authorship from 6.0 distinct countries on average, whereas this figure was 3.3 for KLIMAFORSK publications by the same Norwegian authors.

Cross-disciplinary research

H2020 did not induce any differential change in the deployment of cross-disciplinarity practices as compared to their KLIMAFORSK publications. Norwegian researchers' publications tended to be slightly below the global level in terms of multidisciplinary[32], at either 0.8 or 0.9 (global level is 1.0). Norwegian researchers' publications tended to be below the global level of interdisciplinarity[33] indicator, at 0.6 and 0.7.

Norwegian researchers' publications tended to be well below the global level for their share of publications falling with the top decile of most interdisciplinary papers in their respective subfield and year ($DDR_{10\%}$), at 0.1 and 0.3.

- Science-industry co-publications

A share of 7.2% of H2020 publications included both academic and private firm authors, against 0.1% for KLIMAFORSK publications. The added value of H2020 funding on this dimension was statistically definitive but note that the differential gain measured (+6.5 percentage points) differs slightly from the simple subtraction of the two empirical measurements because of sampling processes applied as part of the bootstrapping.

- Citation impact[34]

The H2020 score on the citation distribution index (CDI) was much above that of the KLIMAFORSK publications (31 to 20; remember that the world level on this specific indicator is set at 0). The CDI

[31] It should be noted however that this formulation of the indicator may be biased against KLIMAFORSK publications, since KLIMAFORSK funding is likely not directly available to RIS country researchers, whereas H2020 funding is.
[32] Average of the relative diversity of disciplines in the research backgrounds of different authors of a given publication - DDA indicators.
[33] Average of the relative diversity of disciplines in the references of a given publication – DDR.
[34] Note that only about 87% of KLIMAFORSK publications and 37% of H2020 publications in the analysis here had been published in 2019 or before and therefore could be included in the citation impact assessment. Because of this situation, most differential changes recorded were not statistically definitive.

indicator is a particularly robust citation indicator that takes into account performances by all papers in a given publication set, whereas other citation impact indicators can sometimes reflect exceptionally high performances by outliers.

- Gender equality in authorships

H2020 publications included at least one woman author in 79% of cases, against 65% of KLIMAFORSK publications, a statistically significant lead for H2020 funding. Authorships on H2020 publications were taken up by women in 25% of cases on average, against 22% of cases for KLIMAFORSK publications. H2020's lead is not significant here.

- Open access

95% of H2020 publications were available under an open access modality, against 90% of KLIMAFORSK publications. H2020's lead was statistically robust.

- Policy-related uptake

The normalized share of H2020 publications cited in policy-related documents was 12 times the world level, against three times the world level for KLIMAFORSK publications. This H2020 lead was statistically definitive. For both H2020 and KLIMAFORSK publications, policy-related uptake is well above world levels, indicating strong performances for this type of societal outcome.

It can be noted that policy-related mentions of peer-reviewed publications should normally be allowed a four-year citation window or more, which has not always been the case for the publications assessed here. The sparsity of observations available on this indicator may somehow inflate normalized effect sizes.

- Beyond academia

Citation windows for uptake of peer-reviewed publications in patents are often set at seven years or more, an interval that has not yet elapsed for the H2020 and KLIMAFORSK publications considered here. Unsurprisingly given this, no observation of citation from patents was recorded for either publication set.

H2020 publication by selected Norwegian authors received six times more than expected coverage in at least one journalistic outlet, against twice the expected level for KLIMAFORK publications. This differential gain was statistically robust, but again, effect sizes tend to be inflated by the general sparsity of altmetrics mentions.

For the remaining altmetrics dimensions considered here, differences in performances between the H2020 and KLIMAFORSK publications sets are not statistically significant.

On all four dimensions, both H2020 and KLIMAFORSK publications recorded levels of altmetric mentions ranging from twice to four times the reference levels in a given subfield and year. That is, both H2020 and KLIMAFORSK publications by selected Norwegian researchers are likely to have been associated with **greater levels of effort** to **increase awareness** and **online attention** towards the findings they contain.

To sum up the **key results of the quantitative analysis**:

Norwegian H2020 publication performances were much above world level and led to KLIMAFORSK achievements on the dimensions of 1) average number of distinct countries of affiliation per publication 2) share of academic-private co-publications; and 3) share of publications with at least one woman author 4) citation impact as captured by the CDI 5) uptake in the policy-related literature 6) coverage in journalistic outlets; and 7) share of publications available in OA.

Both Norwegian H2020 publications and KLIMAFORSK recorded high scores much above the global level on 1) average of relative citations 2) shares of highly cited publications 3) altmetrics.

Publications by selected Norwegian researchers, irrelevant of H2020- or KLIMAFORSK-funding status, scored below world levels on the cross-disciplinarity indicator, without any marked differential change brought about by H2020 funding.

It should be noted that many interviewees stressed that the RCN supports Norwegian research groups in their applications for H2020. Therefore, strong Norwegian researchers and research groups are likely to participate in innovative and important H2020 projects.

2.3.9. Assessment of the benchmarking results

2.3.9.1. Effectiveness

Our evidence shows that KLIMAFORSK is an effective research programme. Considering the original reason why KLIMAFORSK was founded (i.e., individually excellent research groups, but no overall guidance), KLIMAFORSK managed to create coherence within the climate research landscape in Norway. The topics covered by KLIMAFORSK not only exploit the strengths of Norwegian climate researchers (e.g., climate modelling), but they also cover a broad range of relevant topics (i.e., fundamental climate science and the impacts and adaptation measures). The research outputs by Norwegian researchers are internationally well-regarded. The findings of the bibliometric analysis confirm this. Furthermore, due to the outstanding reputation of the Norwegian climate research community, the input from Norwegian researchers is respected both at the European as well as the international level (e.g., JPI and IPCC), according to the interviewees. Norwegian researchers or research groups that want to participate in Horizon 2020/Horizon Europe are supported by the RCN to receive funding.

While the research programme is effective, several factors hindered the achievement of the maximum potential of KLIMAFORSK. For instance, the extent to which cross-disciplinary and interdisciplinary research is implemented is supported could be higher. This is reflected in the bibliometric analysis as well as mentioned by several interviewees who see the efforts of H2020 to achieve this as exemplary. The FRIKLIM instrument aimed to facilitate bold and innovative projects. As these projects can be riskier, interviewees mentioned that sometimes the committees deciding whether or not to fund the application could have granted more promising innovative projects. In addition to that, the integration with industry was also not always optimal. The reason for this includes the existence of other RCN programmes specifically focused on business-oriented research and the exclusion of projects that are focused on the development of technologies. In general, KLIMAFORSK interacts well with other RCN programmes (or nowadays portfolios) by co-funding projects.

Two factors that also had an impact on the effectiveness are related to the changing general context of climate change (research). When KLIMAFORSK was founded, there were relatively few overarching frameworks to tackle these global issues. Since then, the 2030 Agenda and the 17 Sustainable Development Goals have been established as well as the EU Green Deal. In the new Climate- and polar research portfolio, these topics have been integrated better. The introduction of these international goals and policies also shows that over the years climate change (research) has become higher on the agenda. In Norway, the same holds. Some interviewees indicated that at the start of the programme, it seemed that much more funding would be dedicated to the type of research that is supported by KLIMAFORSK. However, in reality, policymakers preferred to dedicate funding to research programmes that also focused on technological developments. Both factors fall generally outside the sphere of influence of KLIMAFORSK, but they indeed hindered the effectiveness of the research programme.

2.3.9.2. Efficiency

Regarding the proportionality of costs to benefits of the research programme KLIMAFORSK, it can be said that KLIMAFORSK is an efficient research programme. With a moderate level of resources, KLIMAFORSK managed to produce excellent scientific output supporting a wide range of stakeholders.

In the context of climate research, it is difficult to compare the costs to the benefits of the programme, as the benefits of climate research – especially for fundamental research – are often built on long-term observations. In addition to that, the research outcomes are often complex and difficult to explain. Even though dissemination of the results is part of the structural objectives – and this went well – the dissemination to all relevant stakeholders remains a difficult task.

Nevertheless, interviewees indicated that, given the context, the KLIMAFORSK output was excellent. Also, specifically with regards to cost-effectiveness, the organisational set-up (i.e. annual call with different themes) contributed to the efficiency as part of the process was standardised. This also means that the free calls were considered less efficient. However, this argument touches upon the previously mentioned struggle between the differences in advantages and disadvantages of the annual thematic rotating calls and the free calls. Interdisciplinary and multidisciplinary projects often bring along more impact on society and science itself, however, the applications and outputs of these projects are much more difficult to assess.

One of the previously mentioned points – that the interaction with the industry was not always optimal and a better integration would have led to a more effective programme – also holds for efficiency. All stakeholders are needed for a well-supported green transition. Industry is a very important player as well, so better interaction with industry could have led to insights and technological developments needed for a smooth green transition.

Nowadays the RCN uses a different approach to funding research programmes, namely a portfolio approach instead of a programme approach. It should be noted that this is not due to the workings of KLIMAFORSK, but it was a general policy shift at the RCN.

2.3.9.3. Relevance

KLIMAFORSK is a research programme that is highly relevant to both Norwegian society and the research community on a regional, national and global level. The topical approach covers all aspects of doing research in the context of climate change. By providing the basic needs of climate research (the topic of climate modelling), it lays the foundation for the more applied topics of identifying the impacts of climate change and means of climate change adaptation. While the actual implementation of the free calls could have been better, it is still a highly valuable asset as it opens up the opportunity for projects that do not necessarily fit the requirements of the pre-determined topics but might be interesting due to the quality or multidisciplinary nature. At the time of the introduction of KLIMAFORSK, the programme anticipated well the emerging needs for research relevant to the green transition. Unfortunately, the funding of KLIMAFORSK was not always as high as expected, as expressed by interviewees, which hindered achieving the full potential of KLIMAFORSK.

Norway is an ‘Associated Country’ and therefore participates in Horizon 2020 but has limited ability to influence the decision-making process with regards to the research direction due to its absence in the European Parliament and the European Council. However, due to the prominence and reputation of Norwegian researchers in climate research, the input of Norwegian researchers and the research outcomes stemming from KLIMAFORSK projects are highly regarded on the international stage. Furthermore, as interviewees pointed out, many of the research topics that are important in Horizon 2020 are similar to those important for Norway.

As for the embeddedness in Norway itself, the programme board included representatives of the different Norwegian user communities, for instance stemming from government agencies and the Norwegian Environment Agency. This ensured that different perspectives are taken into account and therefore the research aligned with policy and societal needs. In addition to that, there were the annual talks with relevant Ministries for research needs that the Ministries deem to be important for their topic and therefore should be covered by the KLIMAFORSK calls. While KLIMAFORSK and the Norwegian climate research community have a good reputation internationally, the connections with the region (i.e., Scandinavia) could soon be improved to gain a better understanding of the regional dynamics of climate research.

In terms of the relevancy of KLIMAFORSK with regards to future research needs, attention for fundamental climate research is rising, as well as for related topics such as biodiversity, is rising as is exemplified by the European Green Deal and the EU Biodiversity strategy for 2030. As previously discussed, the SDGs were not included in the original KLIMAFORSK set-up, but this was because the SDGs were not yet launched. Research supported by the newly established Climate and polar portfolio is considered to be vital to achieving the SDGs. KLIMAFORSK is therefore highly relevant for future research needs. The long-running climate modelling research can be considered a great asset.

One of the structural objectives was also to expand the expertise and applicable knowledge in society. KLIMAFORSK aimed to include a wide variety of stakeholders, such as citizens and businesses, in the projects. Some topics covered research that could be fed into local, regional or national policymaking. For some types of projects, namely, collaborative projects, involving the user community was required. KLIMAFORSK, therefore, aimed to fund research that is relevant to society. The evaluation of KLIMAFORSK also concluded that the use of research-based knowledge has increased as a result of KLIMAFORSK. The integration with businesses went less smoothly. KLIMAFORSK is on this topic lagging behind Horizon 2020.

While the FRIKLIM calls indeed were designed to facilitate innovative and bold projects, the funding of these projects could have been more ambitious as was indicated by interviewees and the bibliometric analysis. Especially the cross- and interdisciplinary topics could have been supported more. This, however, also holds for the H2020 projects with Norwegian researchers. It, therefore, seems something not specific for KLIMAFORSK, but more to the entire Norwegian climate research community.

2.3.9.4. Good practices

The specific organisational set-up where there are three pre-determined themes that on a rolling basis have an annual call and there is also a chance to apply for funding for more innovative out-of-the-box projects in the FRIKLIM call.

KLIMAFORSK also keeps its strategic priorities up-to-date through its programme board and the annual discussions on research needs with the relevant policymakers. By evaluating annually, it can keep its focus on the right topics.

Aside from the scientific objectives, KLIMAFORSK also has the so-called structural objectives, which focus on a wide range of topics that all contribute to developing benefits in general and to society and the research community. Some of these structural objectives are integrated into the calls and types of projects (e.g., collaborative projects and communication and dissemination projects), which act as a means to achieve the structural objectives.

KLIMAFORSK has an important international aspect, where international collaboration is promoted (e.g., joint international calls). To promote the international profile of research groups was also one of the structural objectives.

2.3.10. Outcome dimensions

2.3.10.1. Strategic development

In terms of strategic development, the key question is whether the programme kept abreast with and adapted to changing or emerging global and national situations, such as the Paris Climate Accord and other international commitments.

From the start of the programme, three major topics were used as leading themes. These three topics covered the spectrum from fundamental climate modelling to the impacts of climate change and measures that need to be taken to adapt to climate change. Annually, the priority themes were discussed with policymakers, making sure that the right topics got funded. Nevertheless, according to the interviewees, more could have been achieved if the importance of KLIMAFORSK had resonated more on the political level which at the time focused more on science than on technological output.

While KLIMAFORSK's work programme was developed before the launch of the 2030 Agenda and the 17 Sustainable Development Goals (SDGs), the evaluation committee of KLIMAFORSK indicated that these should be integrated into coming programmes. This does not mean that the topics were not covered, only that the framework was not integrated. KLIMAFORSK also considered and learned from developments at the European level, also with regard to Horizon 2020.

Overall, it can be concluded that efforts towards the Green Transition have been scaled up in the case of KLIMAFORSK. Efforts by Horizon 2020 can be regarded as more successful, however, KLIMAFORSK developed positively over time.

2.3.10.2. Uptake of R&I results

It should be noted that a substantial part of KLIMAFORSK research is fundamental science and within the Norwegian scientific landscape other programmes were focused on the application of scientific knowledge towards creating technological solutions. This context should be considered when comparing the results to other research programmes focused on the green transition.

The bibliometric analysis indicates that on multiple indicators KLIMAFORSK scores much higher than the world average. These indicators include the citation impact, policy uptake, news coverage and altmetrics (KLIMAFORSK publications by selected Norwegian researchers are likely to have been associated with greater levels of effort to increase awareness and online attention towards their findings). KLIMAFORSK scores lower than Horizon 2020, but still scores better than the world average. In terms of public-private cooperation, KLIMAFORSK lagged behind Horizon 2020. These difficulties can be partially explained by the existence of other research programmes that fund less abstract scientific projects. Additionally, most impacts were created within the climate modelling themes as opposed to the more applied topics of climate impact and climate adaptation. The uptake of R&I results has been on the agenda of KLIMAFORSK, but they have not been fully successful in implementing it.

2.3.10.3. Networking and infrastructure

One of the main reasons that KLIMAFORSK was founded was an evaluation of Norwegian climate research stemming from 2012. It concluded that Norwegian research activities on climate were of excellent quality and confirmed that Norwegian research groups were well-respected at a national and international level. However, the overall encompassing ecosystem lacked focus as most research groups worked independently. KLIMAFORSK was set up to help solve this lack of coordination. In that sense, KLIMAFORSK has fully served the networking efforts of the Norwegian climate community. Furthermore, there are excellent connections with international counterparts. While the publications are not as internationally focused (e.g., international co-publications) as H2020, this can be expected considering the size of the programme.

KLIMAFORSK placed high importance on communicating and disseminating the research (results). KLIMAFORSK facilitated the communication and dissemination efforts through multiple measures (e.g., communication requirements for calls and specific calls focused on communication and dissemination). KLIMAFORSK was generally successful with promoting the work within the scientific community and contributing to network building within the climate research community. At the same time, it was less successful in transferring knowledge to other stakeholders.

2.3.10.4. Transdisciplinarity

In terms of KLIMAFORSK's transdisciplinarity, the evaluation committee found that KLIMAFORSK's efforts to be engaged in inter- and transdisciplinary activities were satisfactory. Through other sources, this was confirmed. While there was the intention to promote inter- and transdisciplinary activities, also through the FRIKLIM calls, in reality, it was less successful as compared to what was hoped for. Partially this could be attributed to the fact that relatively little funding was allocated to these FRIKLIM calls. In this perspective, KLIMAFORSK was behind how Horizon 2020 tackled this issue. For this reason, one of the main recommendations made by the evaluation committee was to let interdisciplinary and transdisciplinary research take a prominent place in future climate research.

2.4. Benchmarking Case 4: NSF – US National Science Foundation

2.4.1. Introduction to the international benchmarking case NSF

In the United States of America, one of the main funders of fundamental research is the National Science Foundation (NSF). The NSF is an independent agency of the United States Federal government. It focuses on basic science and funds in a bottom-up manner. It was founded when in 1950 the United States Congress passed the National Science Foundation Act. The specific objectives of the NSF were to:

- promote the progress of science;
- advance the national health, prosperity, and welfare;
- secure the national defence.[35]

The NSF offers a unique approach as compared to the European system and mindset. Focussing on a few sub-divisions for the benchmark such as "emerging frontiers", "chemical, bioengineering, environmental and transport systems", "environmental research and education", and "geo-sciences" is expected to yield competitive benchmarking results. In the context of transformative research, further

[35] https://www.nsf.gov/about/

issues to learn from NSF relate to scientific bias and the handling of low-risk tolerance associated with constrained funding.

2.4.1.1. Study constraints

For this international benchmarking exercise, several constraints were to be taken into account:

- Availability of data. Since the NSF funds research into all science and engineering disciplines, relatively few (evaluation) reports specifically tailored to research into the green transition were available.
- Availability of people to be interviewed. Few people, both from inside the NSF as well as outside, such as researchers, agreed to be interviewed. Among the reasons that were mentioned were their availability, their perceived unfamiliarity with H2020 or their reluctance to some extent to assess the NSF as a whole.

Overall, the data available are considered sufficient for purpose of analysis. Guiding questions for the interview of stakeholders as well as a list of interviewees are included in the annexe. In addition, we conducted an in-depth analysis of the material and (rather rudimentary) research project database available online.

2.4.2. NSF background

The NSF has a comprehensive, overarching mandate to help keep all the fields and disciplines of science and engineering research healthy and strong. The NSF accomplishes this through programmes that support basic research that is conducted by individual researchers or collaborative groups of investigators. The objectives of the NSF on the one hand serve the ambitions to let the US research community advance the scientific frontier and subsequent economic benefits, while on the other hand also contributing to addressing important societal challenges, such as climate change, that the US already is or might be facing in the future.

The annual budget of the NSF is more than $7 billion (ranging from $7.2 billion in the fiscal year 2014 to $7.5 billion in the fiscal year 2017). This funding covers around 25% of basic research conducted by US colleges and universities that is supported by the federal government. Annually, there are about 50,000 requests for funding, and there is an acceptance rate of 20-25%. Whether a request for funding gets awarded depends on two criteria that the NSF uses. The first criterium is *intellectual merit*, which is based on how well a request can contribute to the scientific frontier. The second criterium is *broader impacts*, which includes how well a request can potentially achieve positive societal outcomes and to what extent it helps to tackle specific societal needs.

In the United States, multiple stakeholders are involved in and fund research into climate (change), aside from the National Science Foundation. The United States Global Change Research Program is an overarching programme that aims to bring together different Federal agencies and support synergies between the funding activities of all distinct Federal agencies (see the box "The U.S. Global Change Research Program" below).[36] The United States Global Change Research Program is an important stakeholder in climate research in the US.

[36] National Coordination Office (NCO) for the USGCRP. (2012). THE NATIONAL GLOBAL CHANGE RESEARCH PLAN 2012–2021: A strategic plan for the U.S. Global Change Research Program

Box 1: The U.S. Global Change Research Program

To streamline and coordinate the activities of all US stakeholders the United States Global Change Research Program (USGCRP) was founded in 1990. Thirteen United States Federal agencies take part in the USGCRP:

Department of Agriculture; Department of Commerce; Department of Defense; Department of Energy; Department of Health and Human Services; Department of the Interior; Department of State; Department of Transportation; Environmental Protection Agency; National Aeronautics and Space Administration; National Science Foundation; Smithsonian Institution; and the U.S. Agency for International Development.

The USGCRP was founded to study climate change and other related environmental changes that might have an impact on the United States and its economic and societal well-being. The research that is conducted by the Federal agencies that are part of the USGCRP includes basic research, applied research, communication activities and policy advice.

The USGCRP follows the outline that the decadal Strategic Plan sets out. For instance, the "*National Global Change Research Plan 2012–2021: A Strategic Plan for the U.S. Global Change Research Program*" was the blueprint for the strategy that was followed between 2012-2021. Every three years the new context for the USGCRP and the progress that has been made is touched upon in a *triennial updates*-publication. This *Triennial update* also highlights new developments that the USGCRP will consider in the remaining years from the decadal Strategic Plan

The existence of the USGCRP is important to consider in the context of this benchmark. Not only because it highlights that the NSF is one of the thirteen Federal agencies that fund research into climate (change), but also because to some extent it dictates the context in which the NSF operates. While the NSF is an independent Federal agency, general strategic directions also partially affect the research topics that NSF will fund.

Another important consideration for the context of this benchmark is the political landscape during the period of the benchmarking exercise.[37] A major and influential decision before the period of the benchmark is the 2007 decision of the Supreme Court in the case Massachusetts v. EPA, in which was found that the EPA was authorised to regulate GHG emissions, such as CO2 from motor vehicles as air pollutants under the Clean Air Act. This meant that the EPA could regulate the emission standards from different industries when GHG endanger public health or welfare. During the Obama administration, President Obama published the President's Climate Action Plan in 2013.[38] In this plan, there was a specific chapter "Using Sound Science to Manage Climate Impacts", with a special focus on supporting climate research (change). In 2015, President Obama accepted the Paris Agreement.[39] Therefore, when the Paris Agreement entered into force the United States became a Party. We therefore can deduce that climate change research was high on the agenda for the Obama administration. This however changed when the Republicans won control of the Senate during the 2014 midterm elections. The trend to focus less on climate (research) continued under the Trump administration. For instance, in 2017 the United States withdrew from the Paris Agreement. President Trump also proposed to have the budgets cut for Federal Agencies that fund climate science on multiple occasions, especially for the funds for climate science. Furthermore, the Trump Administration directed Federal Agencies to eliminate one-third of their advisory committees.[40] This meant that multiple agencies researching climate (change) had to deal with decreased budgets or reduced their

[37] Congressional Research Service. (2021). U.S. Climate Change Policy. Retrieved from: https://crsreports.congress.gov/product/details?prodcode=R46947
[38] https://obamawhitehouse.archives.gov/president-obama-climate-action-plan
[39] United Nations Treaty Collection, Chapter XXVII: Environment, "7.d. Paris Agreement," December 12, 2015, https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-a&chapter=27&clang=_en. U.S. depositary notification C.N.10.2021.
[40] https://www.federalregister.gov/documents/2019/06/19/2019-13175/evaluating-and-improving-the-utility-of-federal-advisory-committees

activities in anticipation of the budget cuts. However, not in all cases did Congress agree with the proposed budget cuts for Federal Agencies.[41]

2.4.3. Thematic orientation of NSF

The NSF has a mandate to support all fundamental science and engineering in the United States, except for medical sciences. This is also reflected in the organisational structure of the NSF. The NSF is divided into the following seven directorates:

- Biological Sciences;
- Computer and Information Science and Engineering;
- Engineering;
- Geosciences;
- Mathematical and Physical Sciences;
- Social, Behavioural, and Economic Sciences; and
- Education and Human Resources.

Each of the directorates is headed by an assistant director and each is further subdivided into divisions like materials research, ocean sciences, or behavioural and cognitive sciences.

In addition to that, the NSF also focuses on interdisciplinary activities, through for instance the Office of Integrative Activities, the Division Emerging Frontiers and Multidisciplinary Activities, or the Environmental Research and Education group.

2.4.4. NSF target group

The NSF funds individual scientific investigators or collaborative groups of scientific investigators.

The National Science Foundation is an independent federal agency created in 1950 by Congress through the National Science Foundation Act. While acknowledging that there is no ideal way to determine a priori which research proposals will yield transformative results, NSF aims to ensure that its funding programs have review practices that help identify those proposals that are highly innovative. As previously mentioned, this is based on the two merit review criteria *intellectual merit* and *broader impacts*.

2.4.5. Instruments

The process of applying for research funds is highly standardised at the NSF. The process consists of three phases. The first phase, which has a length of 90 days, includes the announcement of the call and the proposal submission. The opportunities are published on the NSF website as well as Grants.gov. The applicant should upload the finished proposal to NSF via the NSF FastLane System. If the proposal satisfies the NSF requirements, it will be sent for review. If not, the proposal may be returned to make the proposal satisfy the requirements.

The second phase covers the proposal review and processing of the review. First, the reviewers are selected based on their specific or broad knowledge of the topic in scope. The review itself will look at two criteria: Intellectual Merit and Broader Impact. There are scientific, programmatic and technical reviews. The phase continues with a recommendation of a programme officer to the Division Director. This Division Director decides whether to continue the application process or not. This phase may take up to six months.

The third phase, which may take up to thirty days, covers a review process that looks at the business, financial and policy implications of funding the application. Finally, a proposal gets awarded funding.

[41] Nature. (2019). Trump proposes slashing science spending at the NSF. Retrieved from: https://www.nature.com/articles/d41586-019-00851-1

In addition to funding research through core disciplinary programmes, NSF also provides support for facilities, equipment, instrumentation, centres of research, and activities such as workshops that help to advance fields of science. Most of the proposals funded by NSF also support the development of the science and engineering workforce.

NSF also explicitly calls for potentially transformative proposals to help ensure that NSF and the research community maintain a focus on the frontiers of science and engineering.

2.4.6. NSF objectives

The NSF objectives are 1. to promote the progress of science, 2. to advance national health, prosperity, and welfare, and 3. to secure the national defence.

The NSF is the only federal agency mandated to support all non-medical fields of fundamental research into science and engineering. The NSF operationalises its objectives through an ongoing but frequently shifting series of thematically different programmes, some of which relate to the thematic areas of this evaluation exercise.

In the United States, the Government Performance and Results Act (GPRA) (Public Law 103-62) requires Federal agencies, such as the NSF to develop strategic plans that set out the strategy, goals, and means to achieve those goals and to ensure the effectiveness of the agencies. During the period that is covered by this benchmark several NSF strategic plans were developed and published:

- Empowering the nation through discovery and innovation: NSF strategic plan For Fiscal years (FY) 2011-2016
- Investing in Science, Engineering, and Education for the Nation's Future NSF Strategic Plan for 2014 – 2018
- Building the Future: Investing in Discovery and Innovation. NSF Strategic Plan for Fiscal Years (FY) 2018-2022

Aside from the mission and visions of the coming years for the NSF, these strategic plans also set out the strategic goals and core values of the NSF. The strategic goals reflect the NSF objectives and are also aimed to make the NSF effective and efficient. This can be exemplified by the 2014-2018 NSF Strategic Plan where the strategic goals are the following: Transform the frontiers of science and engineering; Stimulate innovation and address societal needs through research and education; and Excel as a Federal Science Agency. While at the core these strategic goals stay the same, in newer versions of the Strategic Plans the goals are adjusted to the newer context in which the NSF operates.

The core values encompass how the NSF always should work. In every decision that is made, these values should be considered. In the 2018-2022 Strategic Plan, the following values were included (in brackets is a brief explanation): Excellence (with regards to science), Public Services (role in society), Learning (support staff), Inclusion (representative of the broader community), Collaboration (focus on teamwork), Integrity (highest standards of ethical behaviour) and Transparency. For each of the subsequent Strategic Plans, the core values were adjusted and added according to the needs at the time. It can be observed that the core values have become more explicit over the years.

2.4.7. Previous evaluations and lessons learnt

We could not find any relevant evaluation reports and interviewees indicated that such reports do not exist.

2.4.8. NSF benchmarking results

The NSF has objectives to improve the progress of science and promote the nation's health, welfare, and prosperity, and help to safeguard national security and defence. The research funded by the NSF that focuses on climate (change) is in line with the general NSF objectives. Increasingly novel methods, tools and knowledge are used to model climate change and which impact climate change has on society.

The NSF is a Federal Agency that funds fundamental research in all science and engineering fields and disciplines, not only research into climate change. It has extensive experience as a funding agency, consequently, the processes for calls for proposal, application, review, and grant awarding are highly standardized. Interviewees indicated that this is one of the features of NSF research funding that is regarded as pleasant. Especially compared to funding processes at other agencies, where reading the calls take a long time, the standardized format allows researchers to not spend an excessive amount of time on identifying potentially interesting call for proposals.

Research that is supported by NSF funding is used by policymakers at different levels of the government. For instance, the NSF, through the USGCRP, has contributed to multiple National Climate Assessments (NCA) – reports that cover climate research in the US holistically, from the findings of climate modelling to more applied research that looks at the effects of climate change on agriculture and human health and welfare. The NCA is published every four years. Additionally, NSF also contributes to the IPCC. Interviewees also indicated that at lower government levels data and research was used for policymaking or strategic planning.

Due to the many scientific fields and disciplines that are covered by the NSF, the NSF is in a great position to fund multidisciplinary projects and bring together different stakeholders that are normally separated by the boundaries of their distinct disciplines. The NSF is aware of this unique position as a funder of a broad range of science and engineering disciplines. There are divisions and advisory committees focused on bringing together distinct scientific fields. For instance, there is the Office of Integrative Activities which plays a coordinating and leading role in programs, which require input from multiple Directorates or new interdisciplinary scientific and engineering concepts. An example of such a multidisciplinary program is the Coastlines and People Hubs for Research and Broadening Participation (CoPe)-program, which is aimed to study the interactions between nature and human ecosystems in coastal areas.[42] This CoPe program is also a good example of research that is truly relevant at the regional or local level. Similarly, there is an opportunity to submit transdisciplinary proposals, that have high-risk but also high potential to transform science, namely through the Research Advanced by Interdisciplinary Science and Engineering (RAISE) proposal. There are therefore multiple ways through which NSF aims to broaden the scope of research activities.

Because NSF climate research activities are heavily integrated with and influenced by the USGCRP, it is important to understand that context as well. During the benchmarking period, the National Global Change Research Plan (2012–2021) was published – a decadal strategic plan for the USGCRP. The plan highlighted how the past two decades focused on observations, process research, and modelling of the physical climate system. Looking at the future, the Program felt poised to integrate important dimensions more fully to the understanding of the Earth system by incorporating complex and critical components such as the roles of ecosystems and human communities. To this end, the Program identified four strategic goals:

- integrate the physical, chemical, biological, and social sciences
- interact with decision-makers about research results relevant to their needs
- advance communication and interdisciplinary education in global change research
- make effective use of assessment results to inform future research activities.

Funding multidisciplinary research was/is one of the focal points for future USGCRP research and therefore also for NSF-funded research. Especially the interaction between climate and humans has become an important topic (as exemplified by the CoPe program). While it has been on the top of the agenda, its execution has been lacking to some extent. In addition to creating synergies by combining different scientific fields, an important policy of the NSF is also to promote diversity and inclusiveness, which also encourages the integration of different perspectives into research. It also exemplifies the shift from only modelling climate change towards investigating the implications for local communities that are or will be affected by climate change. A 2021 report, the National Academies of Sciences, Engineering and Medicine, confirms that in the future the NSF should aim to create an integrated initiative that covers all disciplines that are related to modelling the Earth's system.[43] One of the interviewees mentioned that during the beginning of the benchmarking period Horizon 2020 was

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[42] https://beta.nsf.gov/funding/opportunities/coastlines-and-people-hubs-research-and-broadening-participation-cope

[43] https://www.nationalacademies.org/news/2021/09/national-science-foundation-should-create-next-generation-earth-systems-science-initiative-new-report-says

ahead of the NSF with regards to finding the interface between the natural and human world. However, by collaborating and learning from the European counterpart large steps have been made. It is difficult to discern whether and/or to what extent this shift started during the benchmarking period or afterwards.

Another notable example of the position of the NSF to support groundbreaking research is the National Ecological Observatory Network (NEON). NEON is a nationwide research infrastructure through which terrestrial, aquatic, and atmospheric ecosystems are monitored over an extended period using remote sensing instruments. The data that is generated through this observation facility can be used for many different purposes and scientific disciplines.

Beyond the four strategic goals mentioned by the decadal (strategic) plan of the USGCRP, the USGCRP is also committed to improving its assessment of decision-makers' needs. This translates to providing stakeholders with timely and relevant information. To this end, the Program is committed to implementing a long-term, consistent, and ongoing process for evaluating global change risks and opportunities. This is exemplified by the previously mentioned research outcomes (e.g., NCAs, etc.). Lastly, the Program also recognised the need to communicate beyond immediate stakeholders and reinforce communication with the public through education and engagement in the Program's core research activities. In its triennial 2016 update, the USGCRP more markedly highlights the urgent need to communicate the links between what it calls "climate-related global change" and human livelihoods. It also displays how it has advanced the four identified strategic goals. One example of this is *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (2016).

As the NSF is one of the thirteen Federal agencies that make up the USGCRP, it means that the USGCRP’s goals and agenda-setting strategies are likely to have a meaningful impact on the NSF’s own goals and agenda. Looking at the NSF Strategic Plan (2018-2022), the link between the two is clear. The NSF identified three strategic goals:

- expand knowledge in science, engineering, and learning
- advance the capability of the United States to meet current and future challenges
- enhance NSF’s performance of its mission

The first goal identified by the NSF can be seen as a conducive objective to the first goal identified by the USGCRP. The USGCRP aims to integrate the main scientific fields with the social sciences, while the NSF aims to expand knowledge in the main scientific fields. The second goal identified by the NSF also has strong links to the second goal identified by the USGCRP. The USGCRP aims to provide relevant research to decision-makers to help them make informed decisions, in tandem, the NSF aims to help the United States to advance national health, prosperity, and welfare; to secure the national defence. Lastly, the NSF identified an additional "agency priority goal," aimed at expanding public and private partnerships to enhance the impact of NSF's investments and contribute to American economic competitiveness and security. Within this last goal, the NSF aims at expanding its connection with industry, foundations, and philanthropies to maximize the scientific, economic, and societal impacts of its investments. In this last goal, there is an echo of USGCRP's overall aim for broader communication with the public to make more public the Program's core research activities.

In two previous NSF Strategic Plans communication and dissemination efforts are also mentioned, however, the NSF Strategic Plan (2018-2022) stresses the role of making results and knowledge widely available to the public. According to the plan the NSF intends to use new means to communicate and improve the availability and access to data.

Regarding the organizational set-up of the NSF, the merit review criteria that are used by the committees deciding on whether to award funding to a proposal are noticeably clear. The focus of the criteria is to select the best proposal and fund the best research. While interviewees indicated that this in principle is good, the criteria are initially difficult to understand. Furthermore, interviewees indicated that sometimes it leads to not funding creative, innovative calls because they do not fit into the existing mould. The same holds for proposals from underrepresented communities, however, it should be noted that the NSF places high importance on diversity & inclusion (D&I). Another aspect of the proposal review process is how reviewers are selected. First, reviewers are selected based on their (general or specific) knowledge of the science and engineering disciplines in question or other qualities that support their expertise. However, what is interesting is that proposers can suggest reviewers for their proposals.

Another aspect of the organisational set-up of the NSF is the advisory committees. All Directorates and Offices have external advisory committees composed of external experts that bi-annually provide feedback and advice. The topics that are covered are recommendations on management, the balance of the programme and future directions of research. One of the interviewees mentioned that the members of the advisory committees also contribute to white papers on the future of research in their respective scientific fields.

Interviewees also indicated that the NSF is a lenient partner in terms of how one can spend the funding once it has received the grant award. At some other funding organisations, it is set in stone, when Principal Investigators (PIs) will receive money throughout the project period. The NSF is more flexible in that regard, as they acknowledge that different projects have different funding needs. Interviewees indicated that when getting funded by the NSF, there is room to discuss this and that it is not a problem to have an uneven disbursement schedule. The same holds for time extensions of projects that are already funded.

The turnover of program managers or directors can in some cases be relatively high. This has its advantages and disadvantages. While it discourages favouritism, it also means that in some cases there is little continuity. This means that throughout a funded project there can be multiple program directors which reduces the advantages long-term relationships can bring.

As explained before, the political landscape during the benchmarking period cannot be ignored, as there were profound changes during the period. Another consequence was that, according to interviewees, over the benchmarking period, researchers often found new funding streams, including from corporate partners as well as philanthropists to diversify funding sources. This also reflects the effects of the political influence in the United States as during the Trump administration less focus was put on climate research.

2.4.9. Quantitative benchmarking of NSF

The following quantitative benchmark of NSF was prepared by Science-Metrix. It compares NSF and H2020 with each other and to world averages from several perspectives: International co-publication output; cross-disciplinary research; science-industry co-publications; science-industry co-publications; citation impact; gender equality in authorships; open access; policy-related uptake; and indicators beyond academia.

Science-Metrix identified a subset of US researchers in Scopus that had contributed to both NSF-funded publications and H2020 publications.[44] NSF publications metadata were retrieved from the NSF Public Access Repository and then filtered for thematic alignment with green transition topics. A total of **603** H2020 publications with contributions from these US researchers, and a total of **2,758** NSF-supported publications with contributions from the same set of authors. These two publication sets were mutually exclusive, that is, publications with both H2020 and NSF funding were excluded from the analysis.[45] Below, only statistically robust findings have been retained in the key findings.

International co-publication profiles

A share of 99% of H2020 publications were international co-publications, against 60% for NSF publications by selected US authors.[46]61% of H2020 publications were written by at least one EU27 researcher as either first, last or corresponding author, against 12% in NSF publications. The share of publications rises to 79% when considering the EU27+UK aggregate, capturing the many collaboration linkages between the US and the UK.

[44] It should be noted that Science-Metrix could not determine whether these researchers had been directly attributed funding as part of these two programmes, or whether they had simply contributed to publications supported by these programmes through the contributions of other authors.
[45] All results presented below are point estimates derived from a bootstrapping procedure aimed at measuring margins of errors. These results are complemented by 95% stability intervals that allow an assessment of how statistically definitive the results are. Statistically definitive results should be reproduced in a future comparison between H2020 and NSF based on similar datasets to the one used here, all things being equal.
[46] It should be kept in mind that the US is a Third Country with regard to participation in H2020 projects. Any participation in H2020 projects or publications, therefore, increases its share of co-publications with EU27 researchers by definition.

57% of H2020 publications by selected US authors were international co-publications with contributions from an author from a Third Country as either the first, last or corresponding author. This share was about the same in NSF papers by the same authors. H2020-supported collaborations do not appear to broker higher collaboration figures with other Third Countries for participating US authors, although this finding could also capture stability in the distribution of key authorship roles between US authors instead.

The average number of unique countries per publication in H2020 publications was always above the corresponding figures found in NSF publications for selected US authors, at statistically robust levels.

The thematic baseline figures show that H2020 publications with US authors that are also NSF funded do tend to be much more collaborative than either baseline (2.2 countries per paper on average for H2020 publications in general, 1.7 countries per paper on average in NSF publications).

While differential increases in unique EU27 and ERA countries involved in international co-publications were expected, H2020 publications by US researchers also saw increases in the average number of involvement by Third Countries (from 2.0 to 2.5 unique countries on average per paper). The combination of these observations is that H2020 publications by US researchers recorded authorship from 6.3 distinct countries on average, whereas this figure was 3.0 for NSF publications by the same US authors.

Cross-disciplinarity

Selected US researchers' publications tended to be above world level in terms of multidisciplinarity[47] in their NSF publications, but these scores drop to world level in their H2020-supported publications. The resulting differential decreases were statistically robust.

Selected US researchers' multidisciplinarity in their NSF-funded publications was higher than the NSF baseline (1.4 to 1.2 on DDA), but US researcher's multidisciplinarity in their H2020-funded publications was lower than the H2020 baseline (1.1 to 1.2 on DDA)

US researchers' publications tended to be on the world level on the interdisciplinarity indicator (average of the relative diversity of disciplines in the references of a given publication - DDR), at 1.0 or 0.9. H2020-publications recorded similar levels of interdisciplinarity.

Both H2020- and NSF- funded publications by selected US researchers saw slightly less interdisciplinarity than the corresponding baseline figures, indicating that the selected set of researchers tends to conduct less interdisciplinary research than other H2020 and NSF-funded researchers.

Academic-private co-publication

A share of 22% of H2020 publications by selected US authors included both academic and private firm authors, against 13% for NSF publications. The added value of H2020 funding on this dimension was statistically definitive at +8.5 percentage points.

It can be noted that H2020-funded publications saw more academic-private co-publications (16%) than NSF-funded publications (7%), reinforcing the conclusion that H2020-funding has been more effective at fostering academic-private co-publication NSF funding.

Gender equality in publication authorship

H2020 publications included at least one female author in 78% of cases, against 76% of NSF publications, resulting in roughly equivalent performances.

[47] Average of the relative diversity of disciplines in the research backgrounds of different authors of a given publication - DDA indicators

Authorships on H2020 publications were taken up by women in 22% of cases on average, against 26% of cases for NSF publications. H2020's differential gap is significant here.

The comparisons between the baseline figures do not converge with the comparisons above and therefore indicate that the analysis based on selected US authors may be of low representativeness for the whole of H2020 and NSF.

Citation impact profiles

Note that only about 59% of NSF publications and 47% of H2020 publications in the analysis here had been published in 2019 or before and therefore could be included in the citation impact assessment.

Except for the journal-based citation indicator (FWCS), H2020 publications by selected US authors perform much above their NSF-funded counterparts on all citation impact indicators, at statistically robust levels. These differential increases build on already very strong citation impact profiles. In short, H2020-funding to select US authors takes already world-leading groups of researchers in terms of scientific excellence and allows them to reach truly exceptional citation achievements.

The H2020 score on the citation distribution index (CDI) was much above that of the NSF publications (42 against 33; remember that the world level on this specific indicator is set at 0 and the maximum score is bound at 50). The CDI indicator is a particularly robust citation indicator that considers performances by all papers in a given publication set, whereas other citation impact indicators can sometimes reflect exceptionally high performances by outliers.

More than the majority of publications (69%) issued by H2020 projects with participation from selected US authors fell amongst the top decile of publications most cited for their year and subfield (HCP10%). No less than 20% of publications issued by H2020 projects with participation from selected US authors reached the status of exceptionally highly cited publication within their subfield and year, within the top centile (HCP1%).

In light of these strong findings, it should be repeated that they apply only to the subset of selected US authors that participate in both H2020- and NSF-funded projects. These findings may not inform about the differential performance of H2020 funding for its core European population of researchers, against the achievements of NSF funding for its mainly-US-based population of researchers.

The comparison of H2020 to NSF thematic baselines can help disentangle the general effects of H2020 funding versus effects found specifically for selected US researchers. For citation impact indicators driven by highly cited publications (ARC, HCP10%, HCP5% and HCP1%), H2020 and NSF thematic baselines recorded similar achievements, indicating that the differential gain recorded in favour of H2020 funding was not representative of H2020 funding outcomes outside the selected set of US researchers.

On the CDI, however, there is a positive differential for the H2020 baseline versus the NSF baseline (24 to 20) that converges, although with a smaller magnitude, with the effect found for selected US researchers. It, therefore, appears that H2020 green transition funding has been more effective than NSF green transition funding on balanced citation impact performances of supported researchers.

Propensity towards open-access publishing

93% of H2020 publications by selected US researchers were available under an OA modality, against 84% of NSF publications (data not shown). H2020's lead was statistically robust.

Policy-related uptake

The normalized share of publications by selected US authors cited in policy-related documents was six times the expected for both their H2020 and NSF publications. H2020 funding did not enable differential gains on this dimension against NSF funding.[48]

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[48] It should be noted that mentions of journal publications in policy-related documents are optimally computed using citation windows of 4 years, which have not elapsed here. Therefore, these findings are preliminary and subject to change.

The comparison of policy-related uptake between the H2020 and NSF baselines diverges from the result above, adding concerns about external validity to the limitations already reported above.

Citations in patents

Citation windows for uptake of peer-reviewed publications in patents are often set at seven years or more, an interval that has not yet elapsed for the H2020 and NSF publications considered here. Findings should therefore be interpreted with much caution and are likely to change in future assessments. Nevertheless, it was found that NSF publications by selected US authors have already received citations from patents (60% more than expected), whereas H2020 publications by the same authors have not.[49]

The comparison of uptake of publications in patents between the H2020 and NSF baselines diverges from the result above, adding concerns about external validity to the limitations already reported above.

Journalistic, Wikipedia and social media mentions

Differential changes between NSF and H2020 publications by selected authors were statistically inconclusive on the altmetrics dimensions, meaning it was not possible to conclude robustly that H2020 publications or NSF publications performed better than others on these dimensions.

In all cases, both NSF and H2020 publications performed much above world levels for their likelihood to be mentioned at least once on the platforms of interest. Scores were particularly strong for mentions in journalistic outlets (four to six times world level) or Wikipedia (five to eight times world level).

Except for journalistic mentions, the comparison of policy-related uptake between the H2020 and NSF baselines diverged from the results of the main analysis of selected US authors, adding concerns about external validity to the limitations already reported.

Summary

H2020 publication performances for selected US authors were much above world level as well as compared to the NSF achievements on the dimensions of 1) average number of distinct countries of affiliation per publication 2) share of academic-private co-publications; and 3) citation impact on all major indicators 4) share of publications available in OA.

Both US H2020 publications and NSF recorded high scores much above word level on 1) uptake in policy-related literature and 2) altmetrics mentions.

NSF publications by selected US researchers performed better than H2020 publications by the same researchers on 1) multidisciplinary 2) average publication-level share of authorship held by women 3) citation in patents (although this last finding is preliminary and very susceptible to change in the future, as full patent citation windows elapse).

2.4.10. Assessment of the benchmarking results

2.4.10.1. Effectiveness

Climate research funding by the NSF was an effective way to reach the goals that the NSF strives to accomplish. There is impact on multiple levels: internationally, nationally, regionally, and locally. This can be exemplified by NSF's contributions to the IPCC at the international level, the NCA on a national level and research on extreme events (e.g., droughts, floodings, etc.) on a regional or local ecosystem level. This broad reach demonstrates that the research activities that are conducted contribute to reaching the organizational objectives of the NSF, and even go beyond those objectives. Climate change cannot be looked at from a narrow perspective but should be studied from a holistic, global perspective as environmental ecosystems do not stop at geographical boundaries. Therefore, one

[49] It should be noted that mentions of journal publications in patents are optimally computed using citation windows of 7 years, which have not elapsed here. Therefore, these findings are preliminary and subject to change.

could say that the objectives of climate research implicitly go beyond the organizational objectives of the NSF (e.g., advance national health, prosperity, and welfare). Some interviewees suggested that the NSF could sometimes focus more on international challenges, as a lot of research focuses on complex US-focused issues. This is in line with the NSF organizational objectives and therefore within the boundaries of its mandate. However, as there are great contributions to international activities, it can be concluded that the current situation where there is a combination of studying the various levels of climate change is a positive aspect of NSF's climate funding.

The bibliometric analysis provides additional evidence of the extent to which the NSF research had an impact. First, NSF research results in studies that have a very strong citation impact profile. The H2020 publications by the same group of US authors score better. This can be explained by the fact that the US authors that receive H2020-funding are already a world-leading group of researchers in terms of scientific excellence. This, in turn, allows them to go further and obtain truly exceptional citation achievements. However, when placing it in a broader perspective[50] (i.e., compare the effects of funding for the selected US researchers against the general effects of H2020 funding), evidence suggests a more nuanced picture. For this set of data, the indicators suggest that H2020 green transition funding has been more effective than NSF green transition funding on balanced citation impact performances of supported researchers. With respect to other performance indicators, the NSF research, just like H2020 research, as well as compared to the world level. These indicators include the policy uptake, patents resulting from the NSF research, communication and dissemination methods and the extent to which multidisciplinary research was funded. Overall, the research activities provide good outputs in multiple areas such as scientific impact, multidisciplinary and policy uptake. Consequently, this means that the funding contributes towards reaching the NSF objectives, namely promoting the progress of science, and advancing national health, prosperity, and welfare.

In terms of integrating multiple perspectives in all of NSF's activities, the NSF aims to have a broad representation within the organization, its portfolio, and other activities. For instance, the NSF aims to select a diverse set of reviewers for proposals. Furthermore, activities by the Office of Integrative Activities and the existence of the previously mentioned RAISE proposals allow non-traditional proposals to be funded. As was stressed by multiple interviewees, in the context of the complexity of climate research it is important to consider a broad range of perspectives and bring together knowledge from different disciplines. While it is difficult to say to what extent this has influenced meeting the NSF objectives, these activities certainly contributed to the progress in thinking about the complex challenges at hand. Furthermore, as it is not a one-way street, using scientific knowledge from other fields to do climate research also promotes the progress of science in those fields (e.g., the combination of Big Data and AI in climate research).

Finally, it is important to mention that the political landscape – as an external factor – has influenced the progress of science. Multiple examples show this. For instance, data collection has had to deal with periods of not being able to observe environmental phenomena because of government shutdowns. The resulting data inconsistencies influence the quality of the data. Additionally, the application and review processes and grant awards were halted or postponed during the government shutdowns. Furthermore, as explained before, during the benchmarking period not all research could be conducted as some topics were deemed too politically sensitive. Furthermore, there were budget cuts at the NSF during the Trump administration. While it is difficult to pinpoint what the difference exactly is – since there is no counterfactual – it has influenced the extent to which results were produced and therefore also the impact of the research. An unexpected consequence of the (expected) budget cuts was that alternative funding sources were used (e.g., industry, philanthropists, states, etc.). An indirect result of this is that there are more direct linkages with a broader range of stakeholders. This does not imply that the results of these newly established connections also resulted in a better process, outcomes, or impacts. It merely shows that the connections have become stronger. The bibliometric analysis indeed shows that the subset of H2020 publications by selected US authors that included both academic and private firm authors is higher than the NSF publications by the same authors. Nevertheless, this can be a shift that is ongoing and has not yet resulted in publications.

[50] The previous evidence refers to a subset of researchers, namely US researchers that are both funded by H2020 as well as the NSF.

2.4.10.2. Efficiency

With regard to the administration and management of the NSF, it is highly efficient. The NSF has existed for over 70 years and is a large organization with extensive experience in funding research, which has resulted in optimised and standardised processes. The supporting IT systems are well-developed. As they are integrated into the streamlined project application, selection and funding allocation processes, they work as they should.

In terms of the actual application process for proposals including the merit review criteria which are all clear and well-explained in the documentation. However, it should be noted that interviewees mentioned that it requires time to fully understand the grant award decision process, especially for young researchers. This potentially can lead to not funding bold and innovative projects, also due to conservatism that comes with only wanting to select the best projects and potentially missing riskier projects. The RAISE proposals fund these kinds of projects; however, other stricter criteria apply there.

In terms of efficient implementation of the funding processes by the NSF in the USA, the context of the political landscape should be mentioned as it sets the context. Interviewees mentioned that – due to political sensitivities – some topics in the realm of climate research were not always efficiently funded. It occurred that in the application process to get funding researchers left out certain sensitive terms with regard to climate change in the application texts or titles to avoid being brought into a political discussion that potentially would lead to not getting funding for the research. This self-censoring has dampened the efficiency of the program as it had an impact on scientific freedom and made the entire process more difficult to assess due to the ambiguity it brought along.

The application process could be improved by considering ways to engage with the users more in case there are unclarities about the call for proposals or application process. Interviewees indicated that there is some room to ask for clarification about the call for proposal, or an opportunity to write a one-pager that can be discussed with the program manager. However, there is room to smoothen this process, as the answers to the questions are not always helpful, and different people responding could have different answers. Improving this would result in better proposals and a more efficient proposal writing process for the proposers.

With regard to monitoring and evaluation systems and feedback to policy processes, the NSF has multiple systems in place to ensure that the scientific results lead to constructive outputs. The NSF monitors both portfolio and performance metrics, some of which can be found online through *NSF by the Numbers*[51]. It is unclear whether all metrics are published through this online platform. Furthermore, there are independent audits of NSF's financial performance. Sometimes NSF is also involved in international benchmarking exercises for programs whose ultimate outcomes occur over time frames longer than grant periods. Since the NSF funds a wide range of scientific disciplines, there is a focus on monitoring and evaluating the whole organisation, not specifically the green transition activities. However, through the National Academies of Sciences, Engineering, and Medicine publications are issued to inform policymakers on specific topics, such as climate research and the progress of science in those topics over the years. The topic of these studies can also be related to the USGCRP or are done by the USGCRP themselves. Finally, there is Congressional oversight and each year the NSF needs to request and substantiate the proposed year for the coming year.

2.4.10.3. Relevance

The funding activities of climate research of the NSF are highly relevant to stakeholders' needs. These needs are in line with the overall objectives of the NSF since it contributes to understanding the international, nationwide, regional, and local environmental ecosystem dynamics. The contributions to the NCA and the IPCC show the relevance of the funding by the NSF, as these are prominent and highly valued publications for both policymakers as well as the general public. Furthermore, NEON is a good example of funds that are used to support research at the various levels of the United States' environmental ecosystem.

It should be noted that the NSF is not the only federal agency funding climate research. There are twelve other agencies that, to some extent, are involved and they are united through the main

[51] https://beta.nsf.gov/about/about-nsf-by-the-numbers

coordinating body, namely the USGCRP. The NSF is one of the Parties contributing to it. Through this initiative, the NSF can leverage its activities to engage in multidisciplinary and multi-stakeholder projects. The NSF holds a unique position, also within the initiative, as it funds 25% of all basic science in the United States, and this number is higher for basic science in distinct fields (e.g., the Directorate for Geoscience provides 57% of the fundamental research in environmental sciences[52]).

The NSF has a system through which the thematic areas are kept up to date with technological, scientific, and socio-economic developments. These include the development of the decadal strategy plans, the triennial updates on this decadal plan, and the advisory committees which are composed of leading scientists that consider the future of their respective disciplines. One of the interviewees indicated that a good example of this is that there is a big focus on (and bi-partisan agreement over the importance of) investing in AI and quantum computing. Therefore, research that combines those technologies with climate research is well-funded. The big challenges and known and unknown unknowns that come along with climate change require novel approaches and this shows that the NSF indeed supports such novel approaches.

Finally, as mentioned before, the United States is geographically a large country with many different ecosystems. Therefore, multiple different impacts of climate change can occur in various parts of the country at the same time, such as droughts in some areas and flooding in others. NSF funds research into these 'niche' topics and therefore its activities are highly relevant to local communities as well.

2.4.10.4. Good practices

During the proposal review process, external reviewers are included to assess the proposals. The external reviewers are selected based on their specific expertise on the topic and general expertise on science and engineering to assess the broader implications, or broader societal impacts. The NSF intends to have a broad representation of multiple stakeholders in the review process (including from diverse types of organizations). Additionally, proposers can also suggest reviewers they consider competent. Both the representation of a wide variety of stakeholders as well as the possibility for proposers to propose external reviewers, help the NSF keep up-to-date with use-inspired or upcoming research opportunities.

The calls for proposals that the NSF publishes are very much standardised. They are easy to find and straightforward in terms of readability. Researchers indicated that this is appreciated, as sometimes calls from other funding agencies are difficult to process.

Interviewees indicated that the NSF can be lenient with regard to the disbursement of funding once the grant is awarded to a proposal. Some projects require more funding at the beginning rather than evenly distributed throughout a project, due to larger investments upfront. The same holds for the duration of the projects: there is room to prolong the project if needed. Especially in the context of the inter- and multidisciplinary projects that are needed to research the complex challenges that encompass climate change, the impacts of climate change and adaptation measures, it is very valuable that funders are flexible and interact with the researchers to understand their needs.

At the NSF, advisory committees play an active role in providing advice and recommendations to Directorates and Offices. The members of these advisory committees come from a wide range of stakeholders, including academia, the private sector and policymakers. The main roles of the committees are to be the base of contact between the NSF and the community, provide input, serve as a forum, and monitor the activities. They play a vital role in keeping the research on the scientific and technological frontier; through discussions on the disciplinary needs and opportunities, the role of research and education, integrations of novel methods and other disciplines and the policy implications.

[52] NSF FY 2022 Budget Request to Congress

2.4.11. Outcome dimensions

2.4.11.1. Strategic development

In terms of strategic development, the key question is whether the programme kept abreast with and adapted to changing or emerging global and national situations, such as the Paris Climate Accord and other international commitments.

In this regard, the picture is varied and complex. Although NSF-funded research consequently provided information for important international, national and regional climate assessments (e.g., IPCC and NCAs), shifting political priorities (depending on Administration taking office) and corresponding budgetary changes have had a strong influence on the quality of climate research. This is best illustrated by the US becoming a party to Paris Agreement (in 2015, during President Obama's term), and withdrawing from it in 2017 (during President Trump's administration). During the Trump administration President Trump on multiple occasions proposed to have the budgets cut for Federal Agencies that fund climate science. Due to the power of Congress (which found funding (climate) science of importance) not all proposed budget cuts were approved. Nevertheless, it exemplifies the general context for climate research during the benchmarking period. An unexpected consequence of the weakened climate for science was that alternative funding sources were discovered (e.g., industry, philanthropists, states, etc.). While the effects of this change did not reflect in the bibliometric analysis, it shows that including a wider range of stakeholders in science can be seen as a positive development, especially in the context of climate science (and SDG17). The objectives of climate research implicitly go beyond the organizational objectives of the NSF (e.g., advance national health, prosperity, and welfare). Therefore, it appears that the NSF would have the potential to focus more on international challenges.

Overall, it can be concluded that efforts towards the Green Transition have not been scaled up in the case of NSF as they have within H2020 at the highest political level (through the EU Green Deal).

2.4.11.2. Uptake of R&I results

The evidence base on this aspect is scarce, due to the absence of evaluation reports, and the fact that a substantial part of NSF research is fundamental science. Still, the bibliometric analysis indicates high policy uptake - the share of publications by selected US authors cited in policy-related documents was six times the expected (for both their H2020 and NSF publications).

Herewith interesting observation is also that H2020-funded publications saw more academic-private co-publications than NSF-funded publications (16% vs 7%, respectively), therefore fostering academic-private collaboration and contributing to the uptake of the results.

Next to that, NSF publications by selected US authors have already received citations from patents (60% more than expected), whereas H2020 publications by the same authors do not show such results.

Regarding social media uptake, in all cases, both NSF and H2020 publications performed much above world levels for their likelihood to be mentioned at least once on the platforms of interest. Scores were particularly strong for mentions in journalistic outlets (four to six times world level) or Wikipedia (five to eight times world level).

Also, the advisory committees play a positive role in the uptake of the results, connecting researchers with a wider range of stakeholders, including the private sector and policymakers. They help spot new opportunities, addressing the role of research and education and the policy implications.

2.4.11.3. Networking and infrastructure

NSF-funded climate research activities cannot be assessed without the broader context of climate research in the US. The USGCRP covers all federal agencies that fund climate research. Therefore, all activities that the NSF is involved in within this context have contributed positively to the networking effects. On an annual basis, the NSF funds around 25% of all fundamental research (i.e., in all fields of science and engineering) supported by federal funding that is conducted by US colleges and universities. This number increases when looking at separate directorates that are in the scope of the benchmarking exercise. As fundamental science provides the basis for many other types of (applied) research, as it helps to understand the complex environmental dynamics and ecosystem, the NSF, therefore, plays a vital role in promoting the progress of science, not only for itself but also for the climate research community.

In terms of infrastructure, the NSF funds the National Ecological Observatory Network (NEON), a large-scale research infrastructure focused on observing long-term changes in terrestrial, aquatic and atmospheric ecosystems throughout the US. Without the NSF, such a vast data collection effort and subsequent research would not be possible.

Again, the political landscape has had a profound effect on climate research in the US, and therefore the NSF has not achieved its full potential in building a climate network and a sound research infrastructure. Even though communication and dissemination activities were on the agenda and successful according to the bibliometric analysis.

2.4.11.4. Transdisciplinarity

The NSF funds a wide range of science and engineering fields. There are multiple ways through which the NSF aims to facilitate transdisciplinary research. First of all, there are divisions and advisory committees specifically focused on integrating different disciplines and new approaches to research. Furthermore, there are the Office of Integrative Activities, specific programs such as the CoPe program, and the RAISE proposals.

Evidence from the bibliometric analysis indicates that the selected US researchers tended to be above the global level in terms of multidisciplinarity for their NSF publications. Compared to the H2020-publications of the same authors the NSF publications scored higher. As for interdisciplinarity, the set of H2020- and NSF- funded publications by selected US researchers scored on the global level. At the same time, the analysis showed that generally, this level (for both H2020 and NSF publications) is higher.

Finally, the benchmark showed that over the benchmarking period in terms of transdisciplinarity and finding the interface between the human and natural world, the activities and progress of the NSF- and H2020 activities converged. While both H2020 was ahead in successfully funding this type of research and the topic had been high on the agenda for the NSF, at the beginning of the benchmarking period it was less successful than H2020.

3. Comparative analysis between Horizon 2020 and the international benchmarking cases

The international benchmarking methodology foresees a qualitative comparative analysis of the international benchmarking study case with H2020. The synthesis of results for comparison is based on the overall results of the Green Transition evaluation that are available presently (status: end of September 2022). The presented comparison may be subject to change.

3.1. Quantitative comparison based on bibliometrics

3.1.1. Overall summary

The internal quantitative assessment (i.e., the bibliometric analysis comparing the H2020 SC5 publications to a similar set of publications by the same authors not supported through H2020) indicated that Horizon 2020 has great added value on the two indicators Citation Impact as well as on Open Access.

Generally, this also holds when we compare H2020 to international benchmarks. It should be noted that in terms of citation impact, all international research programs score well above the world average. Horizon 2020 has statistically significant leads in terms of citation impact on ACRP, FONA and the NSF, as for KLIMAFORSK there is no significant difference between the two programs. Especially in the case of the NSF H2020-funding to selected US authors takes already world-leading groups of researchers and allows them to reach truly exceptional citation achievements. At the same time, this brings doubts about whether the samples of the NSF and H2020 represent the total populations of both programs. As for the indicator Open Access, high levels of Open Access for the publications can be seen across the board. Again Horizon 2020 publications have a significant lead as compared to the other research programs. Only for the comparison with FONA, there is no statistically significant lead. In terms of academic-private co-publications, the internal assessment indicates that H2020 as well as the non-H2020 baseline score well on this indicator. This great level is also reflected when compared to the international counterparts, as H2020 significantly score better than FONA, KLIMAFORSK and the NSF. Only for the ARCP, there was no statistically significant difference in this indicator.

Table 28 shows a visual comparison of the different research programmes. Column H2020 SC5 represents an internal comparison. This means that the bibliometric analysis uses a counterfactual analysis composed of comparing the results of H2020-funded publications to an H2020 baseline made up of publications from the same authors as those found in H2020 papers. The other columns represent a comparison between publications from authors that are funded by H2020 and publications by the same authors and those funded through the other research programmes.

Table 26: Qualitative comparison of the research programmes.

	H2020 SC5	ACRP	FONA	KLIMAFORSK	NSF
International Collaboration	-	++	++	o	+
Cross-disciplinarity	o	-	-	o	-
Academic-private co-publication	+	+	++	++	++
Gender-equity	o	+	+	+	-
Citation impact	++	++	++	o	++
Open access	++	++	+	++	++
Policy-related	o	+	o	++	o

outcomes					
Online dissemination	o	o	o	++	o

The combination of the cell colour and the sign within a cell represents how well H2020 scores against the other research programmes or their internal baseline. The light red and "-" indicate that on one of the indicators the counterpart leads with a statistically significant difference. This does not mean that the counterpart leads on all indicators within that category. The grey cells and "o" mean that there was no statistically significant difference between H2020 and the counterpart. The light green and "+" indicate that there was a significant lead for H2020 on at least one of the indicators within the category in favour of H2020. The dark green and "++" indicate that there was a significant lead on all indicators within a category for H2020.

As for the internal assessment, the bibliometric analysis shows mixed results. For instance, the analysis indicates that there are fewer third-country authors at H2020 than at the baseline. The external assessment however shows that in some cases H2020 performs better than other research programmes (e.g., international co-publications). In the case of the comparison with KLIMAFORSK, no statistically definitive differences were found. As compared to the NSF, it stands out that the H2020-funded researchers on average also tend to collaborate internationally more compared to both the H2020 as well as the NSF baselines.

3.1.2. Cross-disciplinarity (least positive)

In terms of cross-disciplinarity, H2020 scores are relatively poor. The ACRP, FONA and NSF score better in indicators that refer to multidisciplinary. This does not hold for the comparison with KLIMAFORSK. Generally, the Norwegian researchers within the scope of this study do not score well on indicators that refer to multi- or interdisciplinarity. Regarding the comparison with the other research programmes on their levels of interdisciplinarity, all research programmes scored rather similarly to H2020.

3.1.3. Academic-private co-publication

The bibliometric analysis of Horizon 2020 showed that H20202 has been more effective at fostering academic-private co-publications as compared to FONA, KLIMAFORSK as well as the NSF. Only when compared to ACRP, there is no statistically significant difference between scores.

3.1.4. Gender equity

According to the internal assessment of Gender-equity, H2020 funding activities do not result in more female authors or having females as prominent authors (i.e., first, last or corresponding author). However, compared to the international counterparts, it appears that H2020 leads on the indicator of having at least one author for three out of the four cases (i.e., ACRP; FONA and KLIMAFORSK). In the case of the NSF, there is no statistically significant difference with H2020. In terms of having female first authors, there are no significant differences between the situation from H2020 compared to respectively ACRP, FONA and KLIMAFORSK. While there are some uncertainties about the external validity of the comparison, there is a significant lead in having female first authors for the NSF.

3.1.5. Policy-related outcomes

For the online dissemination of research outcomes, all international programmes score well, which means that all put in the effort to increase awareness and online attention. There is a statistically significant lead for Horizon 2020 when compared to KLIMAFORSK. This however does not hold when compared to the other research programmes.

3.1.6. Online dissemination

All research programmes show great levels of dissemination.

3.2. Qualitative comparison along selected dimensions

Table 27: H2020 benchmarking with international benchmarking cases along outcome dimensions (++/+/o/-/--).

	Horizon 2020	ACRP (AT)	FONA (DE)	KLIMAFORSK (NO)	NSF (USA)
Strategic development	++ Tight strategic alignment with climate-related political developments and objectives (globally and EU-wide); however, effective uptake and policy impact of strategies taken depends on horizontal policy alignment (e.g., inter-DG/MS cooperation, and the activation and mobilisation of the private/public sectors.	++ Unique institutional set-up, changing annual calls (steering board includes representative from research community and policy making, incl. international experts) Flexible, e.g., new programme initiated to improve policy uptake - good strategic flexibility.	++ Focused on community establishment and institutional capacity, later strategically open and essentially tethered to the private sector (SMEs and large industries) Weakness: civil society, NGOs, and citizens have less been the focus of activities.	++ Rotating themes (climate modelling, impacts, adaptation); combined funding and priority setting by Climate Ministry and Education Ministry. Clear transition- related focus and interdisciplinary, applied focus instead of merely scientific excellence weakness: few funds to transdisciplinary calls	o NSF objectives mirror national priorities; Operationalises its objectives through ongoing but thematically shifting programmes; good monitoring system in place, most results publicly available; progress halted due to the political landscape, therefore full potential was not reached
Uptake of R&I results	+ Uptake of results form a strategic goal in parts of the FP and good in policy-area, at least at EU level; on MS level mixed results: while potential benefit is there, most new member-states lag behind; mixed within Commission (depends on DG)	- Rather weak and virtually only by the funding ministry (for other programme pillars), the concerned research community, less by horizontal policy-making and broader society; especially at the local level and private sector.	+ Uptake by policy (Ministry for Climate Action), less by other relevant ministries. Successful at the regional and local municipal level, SMEs and some larger companies; also, very successful with regard to non-academic R&I institutions	+ Focus on fundamental research, less on R&I and technology development. Good in terms of citation impact and policy uptake, as well as media coverage and altmetrics	+ high uptake scores in terms of citations in policy-related literature and altmetrics; higher number of co-publications with private sector

Networking & infrastructure	++ Largely successful in fostering collaboration between different stakeholder groups and within thematic clusters; while some partnerships may be costly and not entirely efficient, they created unique EU added-value, confirmed by our survey results.	+ Great at establishing and networking an interdisciplinary research community; infrastructure provision rather weak, especially with regard to for explorative research, dissemination, and outreach. However, it has unique programme and research-related links to IIASTA and also IPCC.	++ Effective framework programme with key focus in enhancing large-scale infrastructure, transforming institutions, and financing certain sectors. Networks have been established and fostered. Transitions were achieved; Internationally, good leadership example	+ Managed well linking the scientific communities and networks, especially excellent with regarding international networks. Specific calls for Dissemination and outreach, successful in science promotion Weakness: provision of knowledge and know-how transfer to non-academic stakeholders	+ Infrastructure and services reach international, national, state, and local levels (e.g., with regard to droughts, floods, and ecosystems), not specifically geared towards a Green Transition yet, but to climate change adaption (although not transversally or horizontally).
Transdisciplinarity	++ Can be regarded as gold standard in fostering transdisciplinary research, compared to the benchmarked cases; combined with a boost in uptake, could have a huge potential impact	- Excellent at supporting interdisciplinarity, built great competencies over the years; however, not such much with regard to transdisciplinarity (due to reduced policy, private sector and societal uptake).	+ Inter and multi-disciplinarity are supported well, transdisciplinarity well tackled and addressed but structural barriers remain in place; Civil society and citizens remain a bit outside the focus of FONA	- Relatively small budgets for inter- and transdisciplinary research; it is a priority for KLIMAFORSK however not yet successful	o Successful in fostering science-industry collaboration,non-academic actors involved in agenda-setting; indirectly through USGCRP1

Effectiveness	++ FP is convincingly effective. This is the case across all societal challenges, with projects largely succeeding in achieving their objectives. Funded actions and research appear to provide an important basis towards progress along the impact pathways (although to diverging degrees).	++ Performs well in terms of the scholarly output that is generated, enabled by its funding. In terms of achieving its goals, and given its structural constraints, the programme shows a fairly high rating	++ Programme is highly effective. Especially sustainability transformation research funding (FONA 2 and 3) was effective in reaching the goals that FONA strived to accomplish. Long-term sustainability of funded infrastructure and networks (including expert careers and absorption of transdisciplinary profiles) is still unclear.	++ An effective research programme. Managed to create coherence within the climate research landscape in Norway. The research outputs by the Norwegian researchers are internationally well-regarded (confirmed by bibliometric analysis)	+ Programme is effective, and has impact on multiple levels: internationally (including contributions to IPPC), nationally (contribution to NCAs), regionally, and locally (research on extreme events) However, efficiency was negatively impacted by changing political priorities (and following cuts in funding)
Efficiency	++ Very efficient with regard to management and administration. Coordination of the Green Transition requires steering and managing between different policy areas and along multi-governance dimensions. Serious building of capacities beyond the R&I policy realm is needed.	+ Fares well given its constraints, which are substantial. Manages to process a rather large number of projects quite efficiently and managed to grow and expand (launching the new ACRP Impact funding mechanism)	++ Project administration and proposal management of FONA is highly transparent, professional and efficient. Programme monitoring and transparency could be improved.	++ An efficient research programme. With a moderate resource, KLIMAFORSK managed to produce excellent scientific output supporting a wide range of stakeholders	++ The NSF project/programme management is highly efficient. Optimised and standardised processes, the supporting IT systems are well-developed. Downside: lack of engagement with PIs in case of doubts about the project process.

Relevance	++ Overall, the Framework Programmes are considered to be highly relevant (although the degree of relevance varies across each societal challenge)	o From a Green Transition perspective, ACRP's relevance is regarded as average	++ Good (but not consistently throughout whole period). Programme is not open to everyone (most of funding goes to a few major non-academic research organizations)	++ Highly relevant to both Norwegian society as well as the research community on a regional, national and global level	+ Highly relevant, but not specifically geared towards a Green Transition

3.3. Drivers and barriers affecting impact

Across all four benchmarking cases, a series of essential drivers and barriers that either positively or negatively affect the programme's (or programmes') impact has been identified, from the perspective of the green transition (in a broad sense, as described in the *Societal Challenge 5* synthesis part of this evaluation). Those are closely linked to good practices and lessons learnt – the latter in particular have been made visible with Horizon Europe in mind as well. The following table provides an aggregated and horizontal comparison between the different study cases.

	ACRP	FONA	KLIMAFORSK	NSF
Drivers	• Close Collaboration with the scientific community and relevant ministries • Interdisciplinary focus • Long-lasting collaboration with IIASTA and IPCC • Successful model of inviting inadequate project proposals to improve for resubmission • Academic Excellence (more applied research desired)	• Long-lasting, flexible and adapting programme with focus on institutional, social and economic transformation • Acquisition of large-scale research infrastructure • Successful in its inter and transdisciplinary approach: including the private sector, establishing a relevant science community, establishing new chairs, institutes and funding non-academic research organisations	• Academic excellence • Contribution to IPCC, influence on national and international debate • FRIKLIM open calls (bold and innovative projects)	• Involved in the USGCRP Science-policy interface (National climate reports in context of NSF) • Contributions on all levels (possible due to the scale) • Efficient and long-lasting project/proposal administration system in place • Open calls for multi-disciplinarity • High and excellent publication outcomes • Higher patent uptake (partly due to a different patent culture linked to R&I in the USA)

Barriers	• Uptake limited to financing ministry • CCA requires shorter and faster projects • Transdisciplinarity (involving non-academic stakeholders) requires extra time • Overall funding • Applicability of research is confined by sub-national budget constraints and local business interests	• Sustained private sector involvement only possible for larger companies • Transdisciplinarity • Career path constraints for CCA scholars due to insufficient • Policy uptake beyond the financing ministry • FONA failed to establish as transversal focus within the financing ministry • Wider civil society, esp. NGOs, were not sufficiently included and addressed • Social governance and innovation aspects too little addressed (instead much focus on economic and technological change (starting with FONA 2) • Perception problems of USP and relevance (improved after FONA 2)	• Insufficient inclusion of humanities/social sciences • Insufficient involvement private sector (what type of research is interesting for the private sector) • insufficient multi-disciplinarity • Conflicting priorities at national level (pro-growth vs pro-green focus) • Financial limitations	• Political instability (shifting priorities depending on administration) • While being part of the USGCRP, there is no structure within the NSF specifically focused on CC

3.4. Good practices

3.4.1. KLIMAFORSK (NO)

KLIMAFORSK has a clear organisational set-up laid out in three predetermined annual themes covered on a rolling basis. This provides clarity for the research groups on what to expect. At the same time, there is room to apply for more innovative projects outside the predetermined topics through a specific call, which leaves room for bold and novel ideas. KLIMAFORSK keeps its strategic priorities up-to-date through its programme board and annual discussions on research needs with relevant policymakers. KLIMAFORSK has structural objectives to keep the focus on promoting the general non-typical and societal aspects of its research. Finally, KLIMAFORSK focuses on international collaboration, which helps their research disseminate and supports their reputation in the field.

3.4.2. NSF (US)

During the proposal review process at the NSF, external reviewers are included to assess the proposals. The NSF intends to include a broad representation of multiple stakeholders in the review process (including from diverse types of organizations). Similarly, proposers can also suggest reviewers. Both aspects help the NSF to keep up-to-date with use-inspired or upcoming research opportunities. The calls for proposals are also very much standardised, easy to find and straightforward in terms of readability. The NSF can be lenient with regard to the disbursement of funding and the duration of a project once the grant is awarded to a proposal. This was highly valued by interviewees because not all projects fit into a standard model. Especially in the context of the inter- and multidisciplinary projects that are needed to research the complex challenges that encompass climate change, the impacts of climate change and adaptation measures, it is very valuable that funders are flexible and interact with the researchers to understand their needs. Finally, advisory committees play an active role in providing advice and recommendations to NSF Directorates and Offices. The members of these advisory committees come from a wide range of stakeholders, including academia, the private sector and policymakers. They play a vital role in keeping the research on the scientific and technological frontier; through discussions on the disciplinary needs and opportunities, the role of research and education, integrations of novel methods and other disciplines and the policy implications.

3.4.3. ACRP (AT)

Proposals are reviewed externally by three international reviewers and can be invited for improvement and resubmission, which has been particularly appreciated by researchers, steering board members and policy-makers alike. Similarly, to the NSF, proposers are asked to suggest reviewers who, however, will be included in a well-maintained database and employed only in the upcoming year's review period. Steering board members rotate based on several years of service; Staffing of the Steering board involves thinking about including criteria of excellence, research applicability and policy relevance. Differentiated calls and funding instruments, including a specific call for quick results relevant to national climate-related policy-making, have proven to be successful.

3.4.4. FONA (DE)

The German case is a uniquely situated framework programme with self-claims to world leadership in terms of sustainability transition and research (thus going beyond climate action and research). Best practices refer 1. to an extremely efficient review and project execution process, 2. close ties to the research (academic and non-academic) and policy community, as well as through its instruments, 3. efficiently tackling infrastructure and large-scale transition projects. This holds especially true with regard to R&I (inclusion of the private sector (starting with FONA 2), transforming university infrastructure, curricula and departments, various university-related and non-academic research group establishments and the overall inclusion of an interdisciplinary and even transdisciplinary focus in research and R&I.

3.5. Lessons learnt for Horizon Europe instruments and portfolio development

3.5.1. Lessons learnt from KLIMAFORSK (NO)

Some projects require that a certain percentage come from other sources than KLIMAFORSK. Funding will mostly come from private sector companies. Important to balance perspectives between policy needs and research "end users", something perceived to be difficult. KF project staff feel that they tend to prioritize the user perspective, linked to the fact that the Norwegian industry is a world leader in the green transition. National commercial interests are relevant; Horizon 2020 R&I provides well-received complementary funds. The stability of the calls, since every seven years there are new instruments, is seen as a value-added for KF and enables predictability for the proposers and potential applicants. FP might be better at integrating other stakeholders, focusing e.g., on financing projects that will push the green transition quickly forward.

3.5.2. Lessons learnt from NSF (US)

Currently, the federal government is committed to supporting climate research and science in general. There are many relevant funding agencies for the green transition, for instance, much research is funded by the Department of Energy, as well as the NSF, NASA, EPA etc. In addition, the military sector is concerned with climate change (from a security perspective) and therefore funds a lot of climate-related research. There are also additional funding streams typical for the US R&I system (e.g., philanthropists, corporates/industry/states/state universities, etc.). This has been different in previous years. Nowadays, under the Biden administration, there is an uptick in NSF funding. This can be seen in the funding of huge research centres: large teams; +/- 20 million over 5 years. Another example: NSF TIP: aimed at entrepreneurship, e.g., regional innovation engines REI. A single team could get 160 million over ten years. Team up with a lot of (local) partners. NASA: huge funding earth observations.

3.5.3. Lessons learnt from ACRP (AT) and FONA (DE)

According to all interviewees, all currently existing instruments would benefit from much better integration with Horizon FP instruments – several share doubts about the trend to centralise and expand projects through the mission approach and consortium criteria. Climate-related research (as all R&I research and actions in the SC5) requires often smaller budgets, targeted projects and quick results – especially relevant for local contexts, which would make it necessary to better align bigger European funding schemes with MS funding schemes.

Transdisciplinarity is the big elephant in the room, according to several interviewees: On one hand, it is urgently required, especially in a synthetic, governance-focused and social science-led/oriented way (bringing actors together, effectively enabling social innovation and changing social patterns, behaviours and acceptability, etc.). On the other, there is an unresolved conundrum: the more non-academic stakeholders are involved, the more project time and funds are required, complicating quick results needed for policy making and adaptation.

ANNEX IX: GREEN TRANSITION CASE STUDIES & INTERNATIONAL BENCHMARKING CASE STUDIES

1. Case study 1: Sustainable soil management in Agriculture

1.1. Summary

Soils are key elements of natural biospheres and are the basis for productive agricultural systems and forestry. There is an urgent need for Sustainable Soil Management (SSM) within the European Union as 60-70 % of the European soils are considered unhealthy resulting from current management practices[53]. In particular agricultural soils - the focus of this case study - are subject to excessive fertilization and/or at high risk of desertification. The European Green Deal and the Green Transition have taken up central goals and objectives that have been pursued by SSM, including the goal of a low-input primary production system, ensuring food supply for European Member States and worldwide, as well as the aspect of maintaining and restoring soil ecosystems and making sustainable use of soil ecosystem functions.

The topic of SSM has increased in relevance over the course of the Framework Programmes FP6, FP7 and Horizon 2020 (H2020) and has eventually led to the establishment of the Soil Mission in Horizon Europe. Also, throughout the three work programmes of H2020, there has been a considerable increase in the number of calls and resulting actions on SSM. This evolution of the topic on the European level is in line with various international developments aiming at the Green Transition of agricultural systems, which put a strong focus on soil (i.e. Global Soil Partnership (GSP) established in 2012).

As a result of different national research priorities, the European research community on soil research is very heterogeneous and lacks integration. This case study nevertheless illustrates, for the example of SSM in agriculture, how coordinated European actions have successfully contributed to building a solid base of knowledge and capacities in the Member States, to the mobilization of non-scientific stakeholders and to raising awareness for the topic. Among the 23 analysed projects, with respect to participation, distribution of budget, and coordination, there is strong dominance by EU-14 countries ("old Member States"), whereas not a single project is coordinated by an institution from an EU-13 ("new Member States") country. Due to the long-term processes, it is too early to determine measurable impacts with respect to agricultural methods in practice or soil health. Major hurdles identified by the case study can be seen in a lack of suitable incentives to involve non-scientific stakeholders as well as in the limited capacities, in particular in new Member States, to respond to the incentives and opportunities offered by H2020.

*Key data on the case study are given in **Error! Reference source not found.**.*

[53] European Commission, Directorate-General for Research and Innovation, Veerman, C., Pinto Correia, T., Bastioli, C., et al. (2020): Caring for soil is caring for life. Report of the Mission board for Soil health and food, Publications Office, https://data.europa.eu/doi/10.2777/821504. The report measured soil health based on 6 indicators: 1) Presence of soil pollutants, excess nutrients and salts 2) Vegetation cover; 3) Soil organic carbon; 4) Soil structure including soil bulk density and absence of soil sealing and erosion; 5)Soil biodiversity; 6) Soil nutrients and acidity.

Table 28. Key metadata of case study Sustainable Soil Management'.

Case no. 1	Sustainable Soil Management
Evaluation Question addressed*	Focus on: Effectiveness: 4.2; 4.3.; 4.4.; 4.5/ EU added value: 5.1
Area/SC	Area 1 (Food, Agriculture, Water and Bioeconomy/ Societal Challenge 2, crosslinks to SC5)
SDGs	Zero Hunger (SDG 2), Life on Land (SDG 15), Clean Water and Sanitation (SDG 5), Responsible Consumption and Production (SDG 12)
Programme parts	SFS, RUR
Scope (no. of projects and instruments)	23 projects (RIA, IA, CSA) and EJP CoFund
Key data sources	H2020 work programmes Corda Data Project websites and Strategic documents Interviews
Links with partnerships	EJP Soil
Relevant policies	EU Soil Strategy 2030; Global Soil Partnership (GSP)

1.2. Introduction and Overview

1.2.1. Objectives

The case study identifies and analyses relevant actions related to SSM in agriculture in H2020 and the European Joint Programme EJP Soil.[54] It provides an assessment of the implementation of the Framework Programme and shows how the results and outcomes of the funded projects contribute to the overarching goals of the H2020 programme conception but also analyses how the overarching topic of soils has evolved over the period of H2020 into the Horizon Europe Mission "A Soil Deal for Europe". Against this background, the main objective of this case study is to analyse to which extent H2020 actions enabled an effective approach for creating a basis and pathway for a transformational change in European Agriculture and soil management practices.

1.2.2. Methodology

The case study comprises multiple levels of analysis

- Objective level: Analysis of policies and strategic documents setting the framework for the topic
- Input level: Analysis of H2020 work programmes and identification of relevant calls that potentially contribute to the topic
- Activities level: Projects funded under H2020

The analytical approach commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to the topic of SSM. The identification of relevant

[54] This case study is restricted to agricultural soil, therefore other ecosystems like forests or urban soils and the specific challenges associated with these soil types are not considered.

projects/activities in H2020 combined bottom-up and top-down approaches: In the bottom-up approach, we performed a key-word based search on the complete list of H2020 projects (n=35,325 projects) retrieved from the CORDIS database. In the first step, 550 projects were selected, which contained the term "soil" either in their title or the objective. This long list was subjected to further filtering using keywords like "agri*", "manage*", and "crop*" as well as combinations therefore. Additionally, the long list was subjected to a qualitative content analysis of the title and objectives, yielding a set of 47 projects that treat research questions related to SSM in agriculture. Projects not funded by programme parts within the scope of this evaluation (e.g. MCSA; SME-instrument) were not considered for further in-depth analysis. In the complementary top-down approach, relevant call lines and the resulting projects were screened, as well as further sources of information to identify highly relevant projects that the original key word search had not identified. The final quality-check list comprised 23 projects (Annexe, **Error! Reference source not found.**). These 23 projects were subjected to further qualitative and quantitative analyses. In addition to the project data analysis, we performed five explorative interviews with relevant stakeholders. The interviewees comprised a thematic expert from the European Commission, thematic experts involved in the European strategic processes, a representative of EJP Soil, and project beneficiaries (in some cases, interviewees represented multiple functions). The interviews followed a semi-structured, exploratory approach based upon guidelines referencing the evaluation questions in focus, which focussed on the evaluation dimensions of efficiency, effectiveness, and EU added value. Additional interviews were planned but could not be carried out due to severe difficulties in recruiting interviewees and short-term cancellations. Additional information was retrieved from thematically related interviews (i.e. scoping interviews carried out within the context of this evaluation). For synthesizing the analysis, we triangulated and analysed the findings in relation to the evaluation questions.

1.3. Synthesis of evidence

1.3.1. Green Transition in Soil management

Within the European Union (EU), there is an urgent need for SSM, as 60-70 % of European soils are considered unhealthy. [55] In particular agricultural soils are subject to excessive fertilization, the application of pesticides, compaction and/or are at high risk of erosion and/or desertification. Soil degradation in the EU is estimated to cost more than EUR 50 billion annually. Furthermore, the EU land sector has set the goal to be climate neutral by 2035[56]. In this context, there has been a fundamental shift in the understanding of the role of soils. Their role is no longer restricted to their agricultural value or food and biomass production function. Instead, there is growing recognition of their capacities to provide climate and ecosystem services by acting as carbon sinks ("carbon farming")[57] and their contributions to safeguarding biodiversity.

1.3.2. Strategic policy priorities related to Sustainable Soil Management and the Green Transition

The European Commission has pursued the topic of soil protection over the past two decades: The Soil Thematic Strategy (STS)[58] from 2006 defined the common approach to counter soil degradation and for European and national research funding to close knowledge gaps related to soil protection. Therefore, soils have been an object of increased political attention at the EU and global levels. In 2012 the Food and Agriculture Organisation of the United Nations (FAO) established the Global Soil Partnership (GSP), which aims to promote inclusive policies and soil governance, investments in SSM, and targeted soil research. Moreover, the FAO's Revised World Soil Charter (2015) calls for all parties to ensure that soils are managed sustainably and that degraded soils are rehabilitated or restored.

Healthy soils are the basis for primary production and are a relevant economic aspect for farmers. In addition, soils perform many vital functions and support ecosystem services, including carbon capture and storage and climate regulation, erosion control, water filtration and storage, and biodiversity. Therefore, SSM has the potential to contribute directly or indirectly to numerous SDGs, in particular to

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[55] European Commission, Directorate-General for Research and Innovation, Veerman, C., Pinto Correia, T., Bastioli, C., et al. (2020): Caring for soil is caring for life. Report of the Mission board for Soil health and food, Publications Office, https://data.europa.eu/doi/10.2777/821504
[56] COM(2021) 554 final, 2021/0201(COD); https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:554:FIN
[57] COM(2021) 800 final; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:800:FIN
[58] COM(2006)231 final: Thematic Strategy for Soil Protection; https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52006DC0231&from=EN

SDG 2 "Zero Hunger" (by maintaining and restoring the food production capacities of soils) and SDG 15 "Life on Land" (by protecting and restoring the natural biospheres and soil biodiversity), but also to SDG 6 "Clean Water and Sanitation" (e.g. by reducing water losses and water contamination by fertilizers), and SDG 12 "Responsible Consumption and Production" (i.e. by contribution to the establishment of sustainable food production systems)[59]. When H2020 was designed and introduced, there was no specific and dedicated framework for soil protection at the European level. The proposal for a European Soil Framework Direction - as the first legislation on Soil protection - was withdrawn by the European Commission in 2014. However, with the introduction of the Green Deal and the EU Soil Strategy for 2030[60] (a key deliverable of the EU biodiversity strategy 2030[61]), there has been significant progress in the establishment of a political framework and the introduction of concrete measures to protect and restore soils and ensure their sustainable use. These developments have been strong drivers for the topic of SSM during H2020. In particular, the EU Soil Strategy for 2030 defines the goal of "making SSM the new normal" by assisting regional stakeholders in the Member States in implementing SSM practices for regenerative farming. This dedicated strategy on soil is integrated into a set of related strategies and policies (including the Farm-to-Fork-Strategy, the New Common Agricultural Policy, the Zero pollution action plan, the Circular Economy Action Plan and the Climate adaption strategy). Together, these provide a comprehensive framework for a Green Transition of the agricultural system.

1.3.3. Horizon 2020 programming related to Sustainable Soil Management

1.3.3.1. Development of the topic over European framework programmes

Previous Framework Programmes: In the past two decades, agricultural research has experienced a renaissance after a period where R&I was dominated by basic research questions, which were strongly driven by the potential of emerging genomic research. During this development, capacities in agricultural research were reduced in many Member States. The global food crisis in 2007/2008, and growing awareness of the urgent need to combat climate change and to protect natural resources, including agricultural soils, were important drivers for the re-emergence of applied agricultural research and related topics. This development was accompanied by a growing engagement of the Directorate-General for Agriculture and Rural Development (DG AGRI) in research and innovation. Eventually, the 7th framework programme (FP7) set the ground for the renaissance of applied agricultural research, and this trend continued in H2022 and is continuing in Horizon Europe.

H2020: The relevance of SSM is reflected throughout H2020 with calls addressing the maintenance and improvement of soils in all three work programmes. Importantly, there was a thematic shift from "Soil threats" (i.e. the pure aspect of preventing threats like erosion, decline in organic matter, compaction, sealing, or contamination, or salinization) towards "Soil functions" (i.e. the recognition of the performance of soils and the contributions that soils can make towards the Green Transition goals if managed well and sustainably). SSM is an integral topic within SC2, with all three Work Programmes providing calls on this topic (see below). However, the topic is not restricted to SC2, and further projects have arisen from other programme parts, namely Marie Skłodowska-Curie Actions (MSCA), European Innovation Council SME-Instrument (EIC-SMEInst), but also Spreading Excellence and Widening Participation (Widespread). This indicates that the topic is starting to diffuse from the dedicated programme parts.

Horizon Europe: Most recently, the topic has achieved even higher priority: Under the European Green Deal, healthy soils are considered essential to meet goals related to climate, biodiversity, zero pollution and sustainable food systems, to mention just a few. In 2021 the European Commission presented the EU Soil Strategy 2030, providing a strategic framework[58]. This is also reflected in the strategic agenda setting for Horizon Europe (Horizon Europe), where "A soil Deal for Europe" is one of five Horizon Europe Missions and has set the goal to pioneer the transition towards healthy soils by 2030. The Soil Deal mission is a crucial mechanism to implement the new Soil Strategy and its ambitious goal of ensuring that all soils in the EU are healthy by 2030. From a historical perspective, this development is highly remarkable given that soils now rank on an equal level with key topics such as cancer.

[59] In a broader context, healthy soils also contribute to SDG3 (Health and Well Being), SDG 13 (Climate Action), and SDG 7 (Affordable and clean energy).
[60] COM(2021) 699 final: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0699
[61] COM(2020) 380 final: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX:52020DC0380

1.3.3.2. Contribution of H2020 Work Programmes towards SSM

SSM objectives have been present in all three biannual work programmes of H2020 (**Error! Reference source not found.**). They are mainly covered by Societal Challenge 2 (SC2) "Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy" and the Call "Sustainable Food Security" (SFS), which is present in all three Work programmes. However, the topic is not limited to these calls, and relevant activities are also funded under the Calls "Rural Renaissance" (BBI) and "the Bio-based Industries" (BBI). For example, the 2014/2015 SFS Call referred to the EU Soil Thematic Strategy and mandated that priority be given to improving soil management. Similarly, WP 2016/2017 set the objective to sustain food security but strongly emphasised the resilience of primary production. Concerning soil management, WP2016/2017 strengthened the aspect of international cooperation. WP2018-2020 introduced the EJP Soil, a powerful instrument for building and integrating the European community on soil research.

Moreover, with the third Work Programme, the scope was widened beyond agricultural soils and put additional focus on non-agricultural ecosystems[62]. With the introduction of the Call "Food and Natural Resources," soil received additional attention as an important resource. WP2018-2020 also highlighted the role of soils as a carbon sequestration reservoir and the potential of soil-mediated ecosystem services like fertility and productivity. **Error! Reference source not found.** exhibits calls from the three WPs which refer explicitly to SSM (or relevant aspects thereof)[63]. However, it must be noted that relevant activities are also funded under further calls within SC2 and in other programme parts. In addition, several calls explicitly promote international cooperation with third countries: The Calls SFS-47-2017, SFS-38-2018, and SFS-40-20 include cooperation with China, whereas SFS-35-2019-2020 focusses on cooperation with African countries (**Error! Reference source not found.Error! Reference source not found.**).

Throughout the three work programmes, the number of thematically relevant call topics increased significantly from 2 calls in the 2014/2015 and the 2016/2017 work programmes to seven calls in the 2018-2020 work programme. An increase in budget accompanied this development (see Section **Error! Reference source not found.**, **Error! Reference source not found.**, and section 1.3.4).

Table 29. Relevant Calls in SC2.

Identifier	Call Topic	WP	Instrument
SFS-2-2014/2015	Sustainable crop production [Part B - 2015: Addressing soil-improving cropping systems)	2014/2015	RIA
SFS-4-2014	Soil quality and function	2014	RIA
SFS-50-2017	Supporting international cooperation activities on agriculture soil contribution to climate change mitigation and adaptation	2017	CSA
SFS-47-2017	Management of soil water resources in the EU and China and its impact on agro-ecosystem functions	2017	RIA
SFS-01-2018-2019-2020	Biodiversity in action: across farmland and the	2018-2020	RIA

[62] This case study is restricted to agricultural soil, therefore other ecosystems are not considered in depth.
[63] Note that the calls listed in table 2 are not restricted to SSM in agriculture.

Identifier	Call Topic	WP	Instrument
	value chain		
LC-SFS-20-2019	European Joint Programme on agricultural soil management (COFUND)	2019, continuing into Horizon Europe	CoFund Partnership: EJP Soil
SFS-35-2019-2020	Sustainable Intensification in Africa (RIA)	2019	RIA
SFS-21-2020	Emerging challenges for soil management	2020	RIA
SFS-38-2018	Highly efficient management of soil quality and land resource	2018	RIA
SFS-40-2020	Healthy soils for healthy food production	2020	RIA
FNR-04-2020	Towards a European research and innovation roadmap on soils and land management	2020	CSA to prepare for a mission

1.3.4. Analysis of project portfolio

The project portfolio analysed in this case study comprises 23 projects funded under H2020 (see the full list in **Error! Reference source not found.** in Section **Error! Reference source not found.**). The total EC contribution was EUR 138 million. The individual project budgets ranged from EUR 1.1 million to EUR 8.0 million in terms of the contribution by the European Commission, with an average budget of EUR 5.4 million. The number of participants ranged from 10 to 33, with an average of 20 participating partners. Overall, the field is dominated by large project budgets and complex consortia. In addition to the above calls, a budget of EUR 40 million was earmarked for the European Joint Programme on Soil[64] (funded under WP 2018-2020)[65]. Out of 23 analysed projects, 14 projects (equalling EUR 79,3 million in terms of EC contribution) and the EJP Soil resulted from the calls listed in **Error! Reference source not found.**. In addition, also, further calls and programme parts which were not explicitly dedicated to the topic provided a significant contribution of EUR 59 million or nine projects (equalling EUR 59 million).

1.3.4.1. Type of action

Error! Reference source not found. shows how the budget of the SSM-related projects is distributed over the different types of action and the three Work Programmes. Research and Innovation Actions (RIAs) present the largest share of project types in the project portfolio, both measured by budget and the number of projects (**Error! Reference source not found.**, left). The budget spent on soil management-related projects increased sharply with the third work programme WP 2018/2020, with major actions including the EJP Soil with an EC contribution of EUR 40 million (**Error! Reference source not found.**, right). The majority of the budget was allocated under *Sustainable Food Security*

[64] https://ejpsoil.eu/
[65] The EJP Soil is not included in the quantitative data shown unless indicated otherwise.

(SFS) Call in SC2. However, some projects were also funded under *Rural Renaissance* (RUR) and the *Bio-based Industries* (BBI).[66]

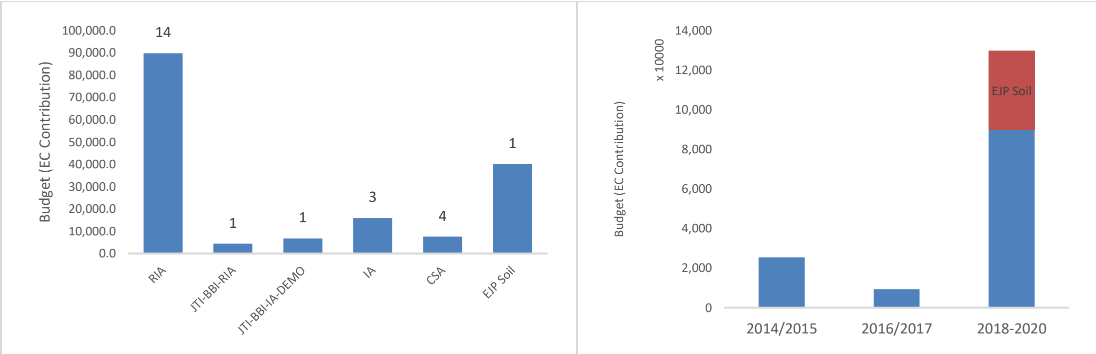

Figure 207. Left: Distribution of budget (EC contribution) over the type of action. The number of funded projects is indicated above the bars. Right: Budget distribution over WPs (EJP soil indicated separately).

1.3.4.2. Participating organizations

Higher or Secondary Education Establishments (HES), Private-for-profit entities (PRC), and Research Organizations (REC) are the organizations benefitting most frequently from H2020 funding in the field (**Error! Reference source not found.**23, left). This indicates that different organizational entities have been well reached. However, when considering the type of action, there were clear differences, e.g. PRCs made up more than half of the beneficiaries within the innovation actions (IAs), while Research and Innovation Actions (RIAs) and Coordination and Support Actions (CSAs) HES and RECs were made up the largest groups of beneficiary organizations (**Error! Reference source not found.**23, right). For RIAs and CSAs, "conventional" research stakeholders, i.e. HES and RECs made up 80% and 76 % of the beneficiaries (**Error! Reference source not found.**, left). HES and RECs also received higher funding on average (an average EC contribution of EUR 548 k and EUR 478 k, respectively) than PRCS (average EC contribution of EUR 257 k) or PUBs (EUR 184 k).

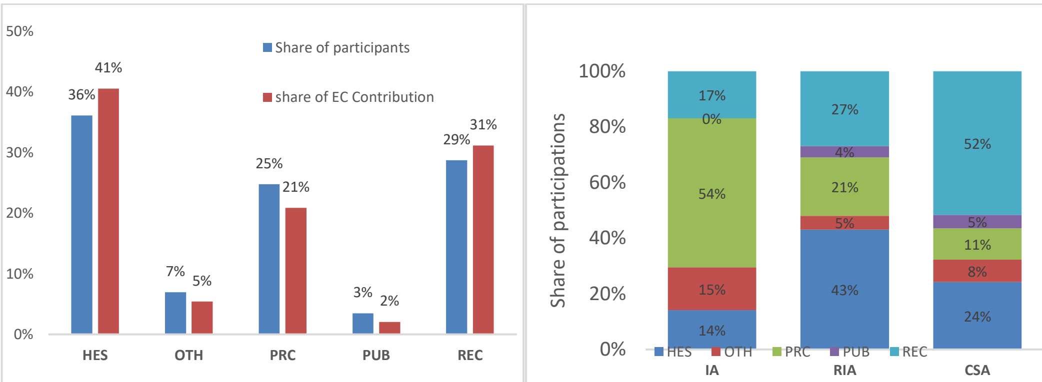

Figure 208. Participation by type of beneficiary organization. Left: Distribution of projects and budget (EC contribution) over the type of beneficiary organization. Right: Participation by type of instruments.

According to experts' opinions in the qualitative interviews, the multi-stakeholder approach was successfully applied in the field as non-academic stakeholders like farmers and farming associations have been mobilized. Due to the applied nature of the topic, their participation was seen as pivotal to the success of the funded actions. Nevertheless, as expectations related to the multi-stakeholder approach have been high, many projects still encountered difficulties in mobilizing local and regional stakeholders or observed that the demand for stakeholder engagement exceeded the capacities of stakeholders. One interviewee reported the increasing phenomenon of "stakeholder fatigue" resulting from the fact that the same stakeholders were approached multiple times. A further obstacle reported during the interviews was that the instruments to compensate stakeholders for their participation are not "fit-for-purpose" as they often do not meet the needs of non-scientific stakeholders, which often prefer not to take over the role of formal beneficiaries due to the high bureaucratic burden.

[66] Further relevant projects are funded under H2020 programme parts which are not included in this evaluation study. These were not considerd in this case study.

1.3.4.3. Participating countries and international cooperation

Among the beneficiaries, there is a strong dominance of EU-14 countries: Three-quarters of the EU contribution was attributed to EU-14 countries, with Spain, Italy, The Netherlands, Germany and Belgium as leading countries both with respect to budget and to the number of projects (**Error! Reference source not found.**), whereas only 11.7 % of the budget was attributed to new Member States (EU-13 countries). Also, EU-13 countries were involved in fewer projects. Moreover, EU-13 countries received smaller budgets (EC contribution) per project: While there are 68 cases in which a budget of EUR 1 million was attributed to an EU-14 country within a single project, there have been only 8 cases in which an EU-13 country received such a high budget (based on EC contribution, data not shown).

All 23 analysed projects have been coordinated by an institution from an EU-14 country, the UK or Norway (**Error! Reference source not found.**), but none by an institution located in a new Member State. With respect to participation, 19 out of the 23 projects in the portfolio had at least one participating institution from an EU-13 member country. These quantitative findings correlate with the evidence from the qualitative interviews in which experts reported difficulties in mobilising participation from EU-13 countries. This was partially explained by the fact that many EU-13 countries, in particular those which belong to the former Eastern bloc, had greatly reduced their engagement in agricultural sciences at the end of the 20th century and redirected their resources towards bio-medical research. As a consequence, many countries are now lacking capacities. A further hurdle was seen in the fact that there was a tendency towards larger and more complex consortia, making it more difficult for less experienced participants to take over the role of the coordinating institution.

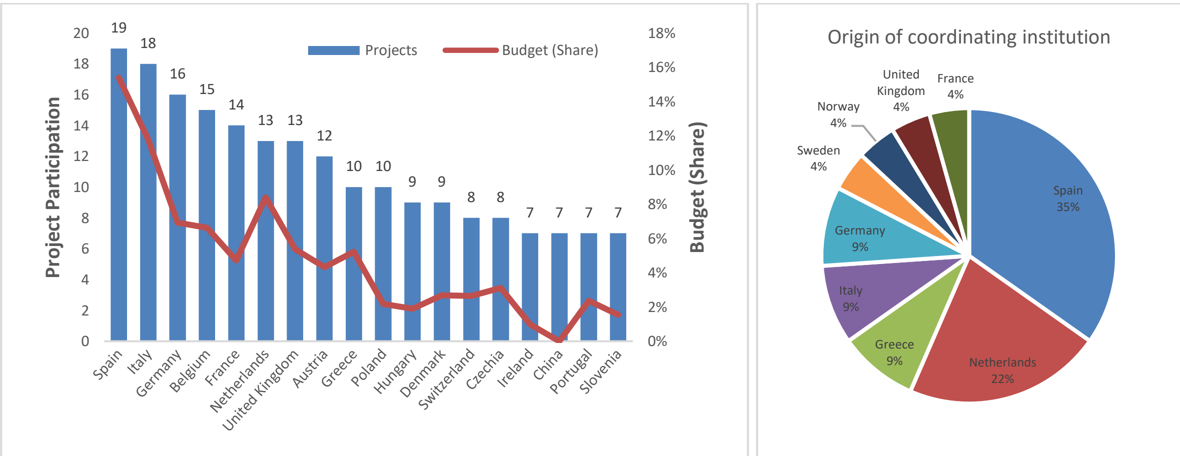

Figure 209. Left: Participation of countries (bars) and share of EC budget attributed to institutions from a given country (line). Top 15 countries are shown. Right: Origin of coordinating institution.

Despite this strong role of the "usual suspects", a network analysis (**Error! Reference source not found.**) revealed multiple interactions of new Member States among each other and with EU-14 countries suggesting that network building has been initiated successfully. This data underpins the qualitative assessment by the interviewed experts that community building was a central goal as well as the major achievement of the H2020 activities related to soil research and soil management. With regard to third-country cooperation, China is in the lead, as it participates in 7 different projects (**Error! Reference source not found.** and network analysis in **Error! Reference source not found.**). This intense involvement exceeds the projects that result from the calls that explicitly included cooperation activities with China (see above). On the other hand, also multiple cooperation with African countries were established but are restricted to the project EWA-Belt," Linking East and West African farming systems experience into a BELT of sustainable intensification" (resulting from the dedicated call) and the CSA CIRCASA "Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture".

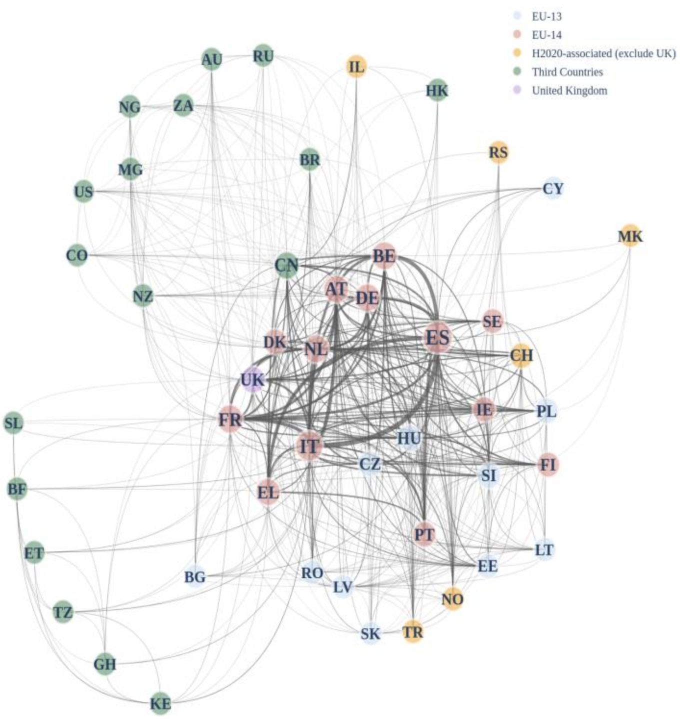

Figure 210. Network analysis.

1.3.4.4. Objectives and topics addressed

A qualitative analysis of the analysed project portfolio revealed that all projects funded under H2020 pursued multiple goals. These could be grouped into five overarching categories: 1) Agricultural Value of Soils; 2) Ecological and Climate Value of Soils; 3) Policy Making; 4) Cooperation; 5) Implementation and Empowerment (**Error! Reference source not found.**).

Agricultural value of Soils	Soil Functions for Climate and Ecosystem Services	Policy	Cooperation	Implemen-tation
• Ensure and intensify agricultural production • Perserve and improve soils as agricultural production system	• Preservation and improvement of soils as ecological ressources • Use of soil systems for carbon capture and sequestration	• Evidence and Advice for future policy making • Monitoring • Harmonization of national soil data	• Building/ strenthening the ERA on soil research • International cooperations	• Training of practitioners • Implementation of novel practices in member states/regions

Figure 211. Objectives of SSM in H2020.

All analysed projects addressed multiple, if not all, of the five objectives shown in **Error! Reference source not found.**. Agricultural performance, with a strong economic component, is a central goal. However, all projects analysed also included an environmental perspective, with several projects aiming at the exploitation of soil functions for environmental services (e.g. the exploitation of carbon capture and sequestration capacities of soils). Notably, the majority of projects within the portfolio pursue the identification and stock-taking of existing - scattered - technologies, data and practices and their dissemination, whereas the development of novel technological approaches typically does not constitute a central goal. This seems to be reasonable, as interviewees repeatedly pointed out that European countries were rich in data and knowledge on soils but suffered from a lack of integration and harmonization in order to take advanced of this wealth. The different projects address various soil-related challenges ranging from pest management, plastic use in farming, and over-mechanical weeding practices to water management.

The project portfolio also strongly reflects the multi-stakeholder approach, as can be seen by the fact that several projects foreground cooperation with local farmers, aim at the development and implementation of knowledge and practices at a regional level, and have established local hubs and sub-networks. As an example, the Best4Soil project[67] has established a network across 20 countries to promote sustainable practices for the control of soil-borne diseases and compiled the available knowledge in a corresponding open-access database. The project SoilCare[68] reviewed soil-improving cropping systems and conducted trials at 16 study sites across Europe, and developed tools for the selection of the most suitable method for a given European region. These two examples show the integration of thematic objectives (agriculture and environment), cooperation and implementation. The project Landmark[69] comprises three pillars (a decision support tool for practitioners, a monitoring scheme for soil functions, and EU policy options). With respect to research and innovations, the aspects of operationalization of existing practices for up-scale and replication, the development of solutions that meet the specific needs of different regions, harmonization of available data and monitoring systems are in focus. Thus, the projects typically try to make existing knowledge available exploitable for the European research and agricultural communities.

1.3.4.5. Coherence and contribution to the goals of a Green Transition

As for the whole of SC2 also, the topic of SSM in agriculture pursues an inclusive understanding of the Green Transition that goes beyond carbon neutrality and reducing the use of fossil resources but aims at making primary production secure, fair and environmentally friendly while better-harnessing soils' ecosystem functions (like carbon storage capacities). All in all, the project portfolio on SSM in agriculture, as analysed in this case study, is in line with the objectives of the Green Transition and the associated strategies and policies, i.e. the Farm-to-Fork and the EU Soil Strategy, even though these were not in place at the time when H2020 and its work programmes were designed. With the high number of projects that have implemented regional and national hubs to inform, train and empower local stakeholders to implement SSM practices, the project portfolio is well in line with the goals of the European Soil Strategy 2030 to make SSM the new normal. At the same time, the project portfolio contributes well to the goals of the Farm-to-Fork-Strategy to ensure sustainable food production and food security without further deterioration of soil fertility.

Interviewees also reported that the introduction of the Green Deal did not lead to a redirection of goals but rather strengthened and reinforced ongoing developments, including the transition towards more sustainable agricultural production, the recognition of soils as valuable natural resources, and the intensification of applied research and stakeholder engagement. In addition, an analysis carried out by the Soil-Mission Support project came to the conclusion that the majority of soil-related projects in H2020 already contribute to the European policy goals defined by the Soil Mission.[70] All interviewees, representing the Commission or the research community, perceived this development as an acknowledgement and justification of their long-standing efforts to promote this topic.

1.3.4.6. Partnership: EJP Soil

The European Joint Programme on Agricultural Soil Management, "EJP Soil Towards climate-smart sustainable management of agricultural soils", started in 2020 and is being funded under the WP 2018-2020 Call "Sustainable Soil Management" for a period of 5 years with a total budget of EUR 80 million (EC contribution EUR 40million; contribution from member countries EUR 40 million). It is a Public-to-Public (P2P) co-funded European partnership coordinated by the French National Institute

[67] https://www.best4soil.eu/
[68] https://www.soilcare-project.eu/
[69] https://landmark2020.eu/
[70] H2020 Soil Cluster Session; 13 January 2021; Final Report; available under: https://www.soilmissionsupport.eu/fileadmin/inhalte/soilmission/pdf/h2020_soil_cluster_session_final_report.pdf

for Agricultural Research (INRA) comprising in total 26 partners from 24 participating countries[71]. Its goals are to strengthen the European research community, construct a roadmap, the identification and filling of knowledge gaps, harmonisation of soil data and information systems across Member States, and the provision of scientific advice to European policies. Therefore, the EJP directly aims to address the need to establish an integrated research community for applied soil research (including soil management) across the European research area and to overcome the inequities in European countries in this field.

Also, the EJP operates on multiple dimensions, including[72]:

- Strategy: Internal Roadmapping for EU Agricultural Soil Management Research and external advice to policy
- Research and Innovation: Internal and external calls
- Dissemination and outreach
- Education, training and capacity building

The programme combines various instruments, including project funding, educational measures, like webinars and PhD schools, support for exchange, like visiting scientist support, and the establishment of a science-policy interface. Until today, three internal (in 2020, 2021 and 2022) and two external calls (in 2021 and 2022) have been published. While access to the internal call is restricted to the designated participating organisations of the EJP Member States, external calls are also open to non-member organisations and countries. The administrative admission restrictions to the internal funding can be seen as a severe hurdle towards maximum output by the programme as relevant and powerful stakeholders may be excluded from the programme. External calls are a mitigation instrument that does not suffice to fully compensate for this effect.

Due to the fact that the first projects were only initiated in 2021 and are thus still ongoing, it is too early to evaluate their outcomes and impacts[73]. However, the first relevant outputs are a strategic European Roadmap, findings on the availability of data and the identification of knowledge gaps. According to experts and programme representatives, the EJP Soil had a relevant effect on national research agendas as it was a trigger for participating countries to take up soil-related research topics. Moreover, this "national mandate" is also seen as helpful on the operational level, i.e. as a facilitator to get access to national and local authorities and stakeholder groups. This was seen as particularly valuable in countries where reservations about European research programmes are high. However, similar effects as for the H2020 programmes can be observed: Eight EU-13 countries (Czech Republic, Hungary, Estonia, Latvia, Lithuania, Poland, Slovenia and Slovakia) participate in the EJP, but none of the 20 projects funded by the first internal call is coordinated by an EU-13 country. Thus, even despite these efforts, there is still a clear gap between the different Member States. AS an instrument to integrate the European research community, the EJP Soil has been designed to mobilize the academic research community primarily. However, at present, there is a growing awareness that there is a need to diversify the research community beyond life sciences and agronomics. In particular, there is a need for social and economic sciences towards the topic of SSM. All in all, the EJP Soil appears to complement the H2020 activities very well as it is in line with the overall goals and objectives of H2020 and provides a valuable contribution towards integrating and harmonizing the research area, but further efforts are needed to empower stakeholders from EU-13 countries and to engage further disciplines.

[71] Participation countries are: France, The Nederlands, Austria, Belgium, Czech Republic, Denmark, Estonia,Finland ,Germany ,Hungary ,Ireland, Italy, Latvia, Lithuania, Norway ,Poland, Portugal ,Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.

[72] The the structure of the EJP Soil and its 10 work packages can be referred to under https://ejpsoil.eu/about-ejp-soil/structure-work-packages

[73] An individual analysis and evaluation of the projects funded within the EJP Soil would have exceeded the scope of this case study.

1.4. Synthesis of Findings related to Evaluation dimensions and Evaluation Questions

This analysis had a focus on the evaluation dimensions "Efficiency", "Effectiveness", and "EU added Value". In the following sections, conclusions with respect to these evaluation dimensions are presented based on the evidence obtained by the qualitative and quantitative analysis.

1.4.1. Efficiency[74]

All in all, interviewees rated the implementation of the H2020 activities related to SSM as efficient. However, interviewees reported that coherence and coordination between programme parts and between the H2020 activities and the EJP Soil activities could be improved. For example, experts reported that the calls from the EJP and the H2020 work programmes lacked coordination with respect to timing and topics addressed. Due to the fact that, at large, the same research communities were targeted, this did not cause problems at the level of content, as the involved researchers had an intrinsic interest in avoiding redundancies. However, with regards to timing, interviewees reported that in particular during the final phase of H2020, the number of calls was too high and exceeded the capacities of the potential beneficiaries to respond to these in an appropriate and high-quality way:

"The coordination could have been better. When the Mission calls were published, many experts were still occupied with the EJP activities and did not have the capacities to respond to the Mission calls." (Interviewee, EJP representative)

However, some beneficiaries also pointed out that due to the fact that many activities were initiated within a short time frame or even took place in parallel, it was not always possible to consider findings from other projects, for example, the CSAs Soil Mission Support and CIRCASA and the roadmapping activities within the EJP Soil took place in parallel making it difficult to take into account the findings of each other.

As shown by the quantitative data analysis, H2020, with its multi-stakeholder approach, was rather efficient in mobilizing new stakeholders and attracting them towards the programme and the topic of soil research:

"The integration of the multi-actor approach in most H2020 soils projects has not only led to more applied research questions. It has also triggered a direct involvement of land managers and other stakeholders in R&I activities in ways that did not naturally happen in “traditional” research. This participatory approach to (soil) research has been crucial for bringing research closer to practice. It has also allowed farmers/other stakeholders on the ground to network beyond their traditional communities and across Member States." (Interviewee, EC representative)

However, interviewees also expressed concerns that the high requirements for accessing the research programmes lead to discrimination of newcomers and further strengthen the position of countries and institutions well established in the field. This, together with the finding that new Member States are strongly underrepresented (among the beneficiaries and coordinators), indicates that further actions are needed in order to empower stakeholders new to European research funding.

1.4.2. Effectiveness

1.4.2.1. EQ 4.1: What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects’ results leading to the achievement of the programme’s objective(s) in this area? What is needed to be able to reach the objectives, and by which timeframe?

There was a strong agreement among the interviewees that the outputs from data stock-taking and harmonization of available soil data are important achievements that provide a solid ground for future activities related to soil management in Horizon Europe. Likewise, H2020, in particular the EJP Soil, has an important effect on building and strengthening the community and raising awareness among different stakeholder groups. Despite these achievements, the interviewees pointed out that the

[74] The dimension of "Efficiency" was analyzed in a comprehensive context, without a focus on specific evaluation questions.

European soil community was still not integrated enough. Therefore efforts to harmonize, integrate and educate will need to be also continued under Horizon Europe, in particular, to empower the EU-13 Member States.

"Europe is rich in soil data, but it lacks harmonization." (Interviewee)

Overall it is too early to measure ecological impacts by quantitative indicators as put forward in the Green Deal and associated strategies. However, according to experts, Soil Management has entered the political agendas and is eventually entering environmental legislation are relevant achievements that lay the ground for a Green Transition of the agricultural system. There was a consensus that H2020 yielded several important prerequisites for achieving these goals not only by providing knowledge as well as information on knowledge gaps but, most importantly, by advancing the topic of Soil Management from a neglected topic towards a topic at the core of a Horizon Europe mission. Even more, the traditional separation between agricultural and environmental research has eventually been overcome, thus providing an important basis for integrating environmental goals in agricultural policymaking. However, for the effects of these activities to unfold and lead to measurable impacts on an ecological level, much longer time frames between 10 and 20 years must be considered, and further requirements must be fulfilled, particularly at the agricultural and environmental legislation level.

1.4.2.2. EQ 4.2: Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc.) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and longer term? Are there any factors that are more or less effective than others, and if so, what lessons can be drawn from this?

Undoubtedly, the increased recognition of the topic of soil management and protection at the policy level has been a central driver for the strong development of the topic both internationally and over the course of H2020. On an operational level, several interviewees reported that the involvement of non-scientific stakeholders was crucial to success and achieving impact but also very challenging. Active local facilitators are seen as important success factors. However, the engagement of local stakeholders is often impaired by systemic or administrative hurdles. In particular, funding instruments are not well designed to meet the needs of farmers and regional associations. Another hurdle is the limited capacity of stakeholders to participate in the programme stemming from the rapid growth in soil-related calls and in the increasing requirement for stakeholder participation. Even though the increased focus on applied research and integration of non-scientific stakeholders was seen as a success by the interviewees, it also became evident that this internal transformation process did not happen without friction. For example, beneficiaries also expressed the desire to strengthen the scientific dimension in this field and missed the engagement by the DG Research and Innovation (DG RTD) because they felt that the needs and requirements to achieve scientific excellence were not always fully met.

In a way, the topic has become a victim of its own success: As the overall recognition of the relevance and urgency of the topic of soil protection and sustainable management, as well as the political commitment to address this topic, have risen rapidly over the past decade, the community is now struggling to build up capacities and expertise to keep pace with new chances and needs. This goes beyond building research capacities in agronomic sciences and the mobilization of farmers, but there is also a growing need to mobilize further disciplines, like economic and social sciences. With the objective of Horizon Europe for transdisciplinary research and the broad mobilization of stakeholders, there is an urgent need to design specific instruments and incentives that meet the needs of the different groups.

For the future, growing pressure for short-term measures to circumvent food shortages as Europe and the world are currently experiencing are severe threats to the achievement up to now but also stress the need for sustainable management practices which combine the ecological as well as productivity aspects.

Eventually, it also needs to be pointed out that most achievements in the field of SSM in agriculture are social innovations (i.e. organizational changes and novel practices) which do not necessarily involve the development of novel technology or new ground-breaking basic knowledge and typically do not yield patents or high-ranking publications. Therefore, progress and success are difficult to measure quantitatively, whereas the effects on the ecosystem level will only unfold in a long-term perspective.

1.4.2.3. EQ 4.3: To what extent have dissemination, exploitation and communication measures enabled reach these outcomes and impacts? What are further actions needed to maximise the impact of the Framework Programme interventions in this area?

Regarding the dissemination among farmers as end-users, it was repeatedly pointed out that the national hubs and facilitators were important factors to success. Interestingly, in some cases, with respect to dissemination, the pandemic situation eventually had a positive effect as a much larger group of people could be reached by virtual and online activities. A further crucial factor for reaching target groups was seen in providing information material in national languages. All in all, beneficiaries had the impression that the scientific community experienced a steep learning curve in stakeholder integration. It can be assumed that this development would not have taken place spontaneously but was triggered by the mandatory requirement for stakeholder engagement set by the H2020 and previous framework programmes. However, it is too early to assess how far the activities of H2020 have led to the long-term adoption of SSM practices among end-users beyond those directly involved in the activities. Beneficiaries reported mixed experiences with disseminating their project outputs to policy makers. While some experts reported that the transfer at the science-policy interface exceeded their expectations and experienced a high interest in their activities and outputs, others reported difficulties in reaching relevant political stakeholders and missed support.

1.4.2.4. EQ 4.4: To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The framework programme has greatly contributed to advancing the topic of sustainable soil research and is very well aligned with the European Policy Priorities and the SDGs. While important prerequisites were established, the European community is now in the position to reach impact. Thus, the H2020 activities represent a preparatory phase towards Horizon Europe and the fulfilment of the Soil Mission.

1.4.2.5. EQ 4.5: To what extent has international cooperation and, more specifically, association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme?

International cooperation with third countries, in particular China and African countries, during the H2020 period indicate that corresponding calls have been effective. Due to the close research cooperation of many European institutions with institutions in China and the fact that cooperation also takes place in projects where the integration of Chinese partners is not mandatory, it can be assumed that academic exchange and excellence in science are relevant motives for this interaction. On the other hand, African cooperation is mainly restricted to dedicated calls suggesting that the funding provided by H2020 was an essential prerequisite in order for these cooperations to take place. The main motive for this cooperation is developmental support in line with the SDGs and the goals of the Green Transition. However, experts also questioned the added value of the H2020 funding compared to national initiatives, especially in the case where long-lasting and close ties exist between European and African countries.

1.4.2.6. EQ 4.6: To what extent have the partnerships achieved their objectives and the objectives of the Framework Programme in this area?

The EJP Soil provides an important contribution towards the integration of the European soil research community and has enabled access to national knowledge and stakeholders. As the European research community in the field of SSM is very heterogeneous, and there are large differences between Member states, the need for measures to harmonize, integrate and unify this European research community seems obvious. However, given that the EJP Soil has only started in 2020, it is too early to in how far it has already achieved some of its objectives, but its design appears to complement ongoing H2020 activities very well.

However, as the number of ongoing activities is high, they are distributed across different programme parts of H2020 (and eventually Horizon Europe), with responsibilities shared across DGs. With this complexity, it might become increasingly difficult to ensure good coordination between the activities of the Framework Programme and the EJP Soil in the future.

1.4.3. EU Added Value

1.4.3.1. EQ 5.1: What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed? Could the stakeholders have implemented their research and innovation in another way, including through other national or regional support?

The H2020 activities have greatly contributed to promoting the relevance of Soil Management and related research activities. While individual countries had already been in a good international position thanks to extant national funding activities, the European Research Area as a whole still lags behind in the international competition. Nevertheless, according to the assessment of the interviewed experts, it has been able to catch up during the course of H2020. With Horizon Europe and, in particular, the Soil Mission, experts see Europe in a good position to catch up even further. Therefore, in particular, with respect to attracting new stakeholders to the topic, H2020 has provided a clear added value.

However, in order to create an impact, it must be kept in mind that the agricultural sector is heavily influenced by agricultural policies, most notably, the Common Agricultural Policy. Therefore, the added value provided by European research funding can only be exploited when accompanied by corresponding modifications of environmental and agricultural legislation.

1.4.3.2. EQ 5.2: What is the value resulting from partnerships in this area that is additional to the value that could result from interventions carried out at the regional or national level?

Due to national programmes, soil research is very advanced in some Member States, whereas in particular, EU-13 countries lag behind. This is partially due to national programmes dedicated to soil research in many EU-14 countries. A CoFund activity, the EJP Soil has been successful in mobilizing Member States to include the topic of SSM in their national research and innovation agendas. Moreover, with this national mandate, access to national stakeholders was facilitated. However, the still-lower budgets of EU-13 countries and the absence of their researchers from the circle of coordinators indicate that differences in potency remain, and it will take further efforts to overcome them.

A further objective which would have been difficult to achieve by national means alone is the harmonization of soil data and monitoring systems. This is an on-going progress which needs to be coordinated at the European level.

1.5. Conclusion

This case study illustrates how the topic of SSM has evolved from a "niche topic" towards one of highest relevance, i.e. at the level of a Mission in Horizon Europe. H2020 and its activities on SSM coherently continued the development which had been initiated in previous Work Programmes.

SSM is an important approach toward achieving a Green Transition and has the potential to contribute to various objectives, including food security, environmental protection and carbon neutrality. The case study illustrates how H2020 has successfully contributed to promoting the topic in various member states and the mobilization of new stakeholder groups. Importantly, major achievements in this field do not follow the straight-forward pathways as often assumed for technical innovations but arise from the complex integration, harmonization and application and translation of existing knowledge into practice and the accompanying social and economic transformation processes. However, it also reveals that these processes are only evolving slowly. Research and innovation will provide essential prerequisites, but eventually, it will depend on the future legal framework for the effects to unfold.

1.6. Annex

1.6.1. Project Portfolio

Table 30. Project portfolio.

Project-ID	Acronym	Full title	Type of action	CALL-ID
101000258	SMS	Soil Mission Support: Towards a European research and innovation roadmap on soils and land management	CSA	H2020-FNR-2020-1
727848	CERERE	CEreal REnaissance in Rural Europe: embedding diversity in organic and low-input food systems	CSA	H2020-RUR-2016-1
774378	CIRCASA	Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture	CSA	H2020-SFS-2017-1
817696	BEST4SOIL	Boosting 4 BEST practices for SOIL health in Europe	CSA	H2020-RUR-2018-1
101000256	WeLASER	SUSTAINABLE WEED MANAGEMENT IN AGRICULTURE WITH LASER-BASED AUTONOMOUS TOOLS	IA	H2020-SFS-2020-1
101000554	NOVATERRA	INTEGRATED NOVEL STRATEGIES FOR REDUCING THE USE AND IMPACT OF PESTICIDES, TOWARDS SUSTAINABLE MEDITERRANEAN VINEYARDS AND OLIVE GROVES	IA	H2020-SFS-2020-1
101037128	PestNu	Field -testing and demonstration of digital and space based technologies with agro-ecological and organic practices in systemic innovation	IA	H2020-LC-GD-2020-4
837583	B-FERST	Bio-based FERtilising products as the best practice for agricultural management SusTainability	JTI-BBI-IA-DEMO	H2020-BBI-JTI-2018
887648	RECOVER	Development of innovative biotic symbiosis for plastic biodegradation and synthesis to solve their end of life challenges in the agriculture and food industries	JTI-BBI-RIA	H2020-BBI-JTI-2019
101000210	PAPILLONS	Plastic in Agricultural Production: Impacts, Lifecycles and LONg-term Sustainability	RIA	H2020-SFS-2020-2
101000224	TUdi	Transforming Unsustainable management of soils in key agricultural systems in EU and China. Developing an integrated platform of alternatives to reverse soil degradation.	RIA	H2020-SFS-2020-2
101000407	MINAGRIS	MIcro- and NAno-Plastics in AGRIricultural Soils: sources, environmental fate and impacts on ecosystem services and overall sustainability	RIA	H2020-SFS-2020-2
633945	FATIMA	FArming Tools for external nutrient Inputs and water MAnagement	RIA	H2020-SFS-2014-2

Project-ID	Acronym	Full title	Type of action	CALL-ID
635201	LANDMARK	LAND Management: Assessment, Research, Knowledge base	RIA	H2020-SFS-2014-2
635750	iSQAPER	Interactive Soil Quality Assessment in Europe and China for Agricultural Productivity and Environmental Resilience	RIA	H2020-SFS-2014-2
677407	SOILCARE	Soil Care for profitable and sustainable crop production in Europe	RIA	H2020-SFS-2015-2
773903	SHui	Soil Hydrology research platform underpinning innovation to manage water scarcity in European and Chinese cropping systems	RIA	H2020-SFS-2017-2
817819	SoildiverAgro	Soil biodiversity enhancement in European agroecosystems to promote their stability and resilience by external inputs reduction and crop performance increase	RIA	H2020-SFS-2018-2
817946	EXCALIBUR	Exploiting the multifunctional potential of belowground biodiversity in horticultural farming	RIA	H2020-SFS-2018-2
818346	SIEUSOIL	Sino-EU Soil Observatory for intelligent Land Use Management	RIA	H2020-SFS-2018-2
858375	WATERAGRI	WATER RETENTION AND NUTRIENT RECYCLING IN SOILS AND STREAMS FOR IMPROVED AGRICULTURAL PRODUCTION	RIA	H2020-SFS-2019-2
862756	OPTAIN	OPtimal strategies to retAIN and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe	RIA	H2020-SFS-2019-2
862848	EWA - BELT	Linking East and West African farming systems experience into a BELT of sustainable intensification	RIA	H2020-SFS-2019-2

1.6.2. Distribution of budget over Work Programmes

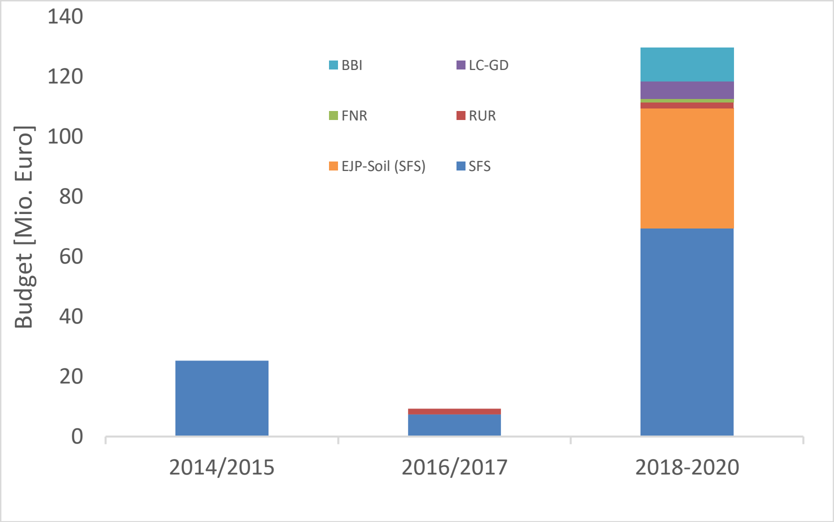

Figure 212. Distribution of budget (EC contribution) by work programme and Call.

2. Case study 2: Exploration of marine environments for industrial valorization

2.1. Summary

The biodiversity of marine and maritime ecosystems has a high potential to contribute to innovative and sustainable products for better health, environmentally-friendly processes and well-being. To explore the variety of marine bioresources and to exploit its potential for economy and society, the Blue Growth focus theme of Horizon 2020 addresses these challenges H2020 calls together with activities form Partnerships (ERA-NET Blue Bioeconomy, JU BBI, EIT Food).

The case study identifies and analyses those relevant actions. It reveals that many projects achieved significant technical and economic progress, and in some cases, commercial exploitation has started. Moreover, the actions contributed to forming networks along and across seas, competence building for commercial activities (e.g. training regarding IPR issues) and a better understanding of needed policy steps (i.e. in terms of a roadmap). Still, significant market barriers (upscaling, regulation, consumer acceptance) are ahead, and the contribution to SGDs by marine bioresources is mostly assumed in H2020 given. The current step of EU policy towards addressing more explicitly the Green Transition by launching the EU mission Restore our Ocean and Waters and the started EU Algae Initiative, is an important step forward.

2.2. Introduction and overview

2.2.1. Objectives

The case study identifies and analyses relevant actions related to the exploitation of marine bioresources in H2020 and relevant partnerships for this topic.

It provides an assessment of the implementation of the Framework Programme and shows how the results and outcomes of the funded projects contribute to the overarching goals of the H2020 programme conception. Hence, the main objective of this case study is to analyse to which extent Horizon 2020 actions enabled an effective approach for exploiting marine resources that can be further developed in the sustainability-driven concepts in Horizon Europe.

2.2.2. Methodology

The analysis comprised six Horizon 2020 calls & relevant activities of three Partnerships (ERA-NET Blue Bioeconomy, JU BBI, and EIT Food). The time horizon covered with the analysis is 2014 – 2020. The number and type of instruments analysed are 7 RIAs, 4 CSAs, and 3 IAs. An overview is provided in the Annex of this case study.

The analytical approach commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to the use of marine bioresources (e.g., Blue Growth Strategy). We then identified relevant project actions in Horizon 2020 based on an in-depth study of topics in the work programme and an analysis of the partnerships' websites. For the identified projects, relevant data from Cordis/Corda have been compiled, analysed, and complemented by additional sources like project websites.

In addition to the project data analysis, we performed seven interviews with relevant stakeholders. The interviewees comprised representatives from the EC, thematic experts involved in the European strategic processes, representatives of ERA-NET, and project beneficiaries (research institutions, associations, SMEs). The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus.

For synthesizing the analysis, we triangulated and analysed the findings in relation to the evaluation questions.

2.3. Synthesis of evidence

2.3.1. Green Transition in marine bioresources

While seas and marine areas are heavily affected by climate change and pollution, the exploitation of its resources potentially addresses the overarching challenges of the Green Transition (Petersen et al. 2021). Marine organisms and derived compounds are important resources in relation to several EU priorities such as carbon neutrality, innovative, healthy and sustainable food systems and sustainable and circular economy (EC 2022). They can be the source of healthier food, contribute to water remediation, reuse or degrade waste, and avoid pollution. While sustainable cultivation in seas requires energy and resources, it is also considered a sustainable alternative to agricultural production and related intensification. Hence, the exploitation of marine bioresources is expected to contribute to different SDGs, in particular to Life Below Water (SDG 14) but also Industry, Innovation and Infrastructure (SDG 9) and Good Health and Well-Being (SDG 3).

However, related activities are still in their infancy, and production is on a low industrial scale. Consequently, the impact on the environment, food security and health are still limited. Moreover, the potential amount of available bioresources for cultivation has limits, and a transition to a blue bioeconomy can only take part to a limited degree. Some stakeholders regard the further exploitation of the marine environment even more critically and fear a decline of biodiversity and an imbalance of the marine ecosystem by exploitation of marine bioresources, as, e.g. already the case for fishing in many seas (e.g. Ertör and Hadjimichael 2021).

Hence, sustainability is not given per se, but the transition to an increased usage of blue biomass calls for new cultivation technologies and processing methods, its inclusion in marine spatial planning, and the development of circular concepts, including the use of waste and residues as feedstock and inclusion. Finally, consumer acceptance, inclusion of societal needs, and stakeholder engagement in the transition process are important.

2.3.2. Strategic policy priorities related to Sustainable Marine resources and the Green Transition

The EU's governance of marine and maritime areas has significantly transformed in the last two decades (Guerreiro 2021). In 2006 the European Union adopted a more holistic governance approach to analyse the state of the art and the future potential of different sectoral maritime policies. The integrated Maritime Policy aimed to combine scientific and technological advances with new economic uses of the maritime space to coordinate different sectorial policies and actively involve stakeholders. The EU approved its Integrated Maritime Policy (EC, 2007), followed by the Marine and Maritime Agenda for Growth (EC, 2012a), which introduced the Blue Growth Strategy.

The Blue Growth strategy pointed out the potential contribution of the blue economy "to the EU's international competitiveness, resource efficiency, job creation and new sources of growth whilst safeguarding biodiversity and protecting the marine environment, thus preserving the services that healthy and resilient marine and coastal ecosystems provide" (EC 2012a, p.3). The strategy aims to support long-term sustainable growth in different marine and maritime sectors and identifies five sectors where additional efforts at the EU level have to be taken. One of these areas is the blue bioeconomy – which presents a part of the exploitation of marine resources. Here a strategic approach to research and innovation was seen as needed to reduce technical bottlenecks to become a more attractive area to investors and move from the developmental stage to the commercialisation of innovative products. As one action, a study was commissioned, which points out specifically the difficulties and costs of sampling the huge diversity of resources and the dependence upon SMEs to translate R&D results into a marketable commercialised product. (Ecyorys 2014) Moreover, the study identified legislative barriers and uncertainties.

During the H2020 programme, different EU policy initiatives were launched that are relevant to exploiting marine bioresources, such as the 2018 update of the European Bioeconomy strategy, the Green Deal, the Farm to Fork Strategy or the EU biodiversity strategy for 2030.

In 2021, the European Commission communicated in " A new approach for a sustainable blue economy in the EU - Transforming the EU's Blue Economy for a Sustainable Future" the aim to integrate ocean policy into Europe's new economic policy (EC 2021). This should ensure that the blue economy plays a major role in implementing the European Green Deal, and the Communication proposes a further development from blue growth to a sustainable blue economy. Therefore, the document outlines that economic activities at sea and coastal areas need to reduce their cumulative impacts on the marine environment. Value chains need to transform to contribute to climate neutrality, zero pollution, circular economy and waste prevention, marine biodiversity, and coastal biodiversity resilience and responsible food systems. The exploitation of marine resources presents a minor issue in the communication. Still, it is at least mentioned as a relevant activity for providing concrete solutions to produce materials, enzymes, food supplements and pharmaceuticals and included as relevant as the R&I theme. Moreover, the Communication announced a dedicated Algae initiative in 2022, and a public consultation on the EU Algae Strategy has started.

2.3.3. Horizon 2020 programming related to the exploitation of marine bioresources

The identification, exploitation and technological implementation of maritime resources are addressed mainly in the first two SC-2 work programmes (2014-2018) of H2020 in the "Blue Growth" program.

The relevant calls focus on molecules, especially enzymes and algae, as important resources in biotechnological innovation. Also, technologies that enable the industrial upscaling of developed applications are addressed.

The Work Programme 2014/2015 addresses the exploitation of the rich marine, particularly the vast reservoir of enzyme resources, to develop novel, improved or more economical and eco-friendly end-products and processes. Therefore, the discovered molecules should be examined for their characteristics, always concerning the practical use of their features. Moreover, the bottlenecks for upscaling potential products from the innovations discovered should be identified, as well as possible legal problems and issues related to (intellectual) property rights.

The work programme 2016-2017 focuses on algae as a specific marine resource. It expects the development of marine and innovation, demonstrating the technical and economic feasibility of environmentally sustainable large-scale algae biomass. Therefore, it is essential to scale up products with large potential to bring them closer to the market in an economically, environmentally and socially sustainable manner. Regarding the latter, examining social acceptance of the products and the inclusion of stakeholders is expected.

In addition, several calls for CSAs in WP 14/15 and 16/17 ask to support the main technical undertakings. By networking researchers and important stakeholders across different sectors and countries in the European area and partly international ones, duplication and fragmentation of research should be prevented. Therefore strategic approaches and R&I roadmaps should be developed. Moreover, the CSAs cover different sectors of the Blue Growth Area and activities, the exploitation of bio-resources, and aim for better integration and alignment of these activities, e.g. in Maritime Spatial Planning.

The WP2018-2020 addresses the sustainable harvesting of marine biological resources. Therefore, activities should support effective marine harvesting that sustainably manages and protects marine ecosystems. Moreover, activities towards sustainable, resilient exploitation, while at the same time understanding the ecosystem in the Black Sea, are funded that aim to facilitate business activities. Those may relate – but not necessarily –to the use of bioresources.

In summary, the work programs aim to create a competitive and innovative European economy by exploring the technological potential of marine resources and exploiting an effective integration with other marine sectors and activities to minimize undesired effects on ecosystems.

2.3.4. Analysis of project portfolio

The project portfolio of this case study comprises 14 projects related to marine resources. The portfolio covers four CSAs, including those included that only partly relate to the use of marine bioresources but are embedded in the broader Blue Growth topic. This composition significantly affects all “average “ characteristics as CSAs differ in size, participation, etc., from the other instruments. These peculiarities are, as far as possible, considered in the interpretation.

The project budgets range from EUR 277.260 to EUR 5.1 million, with an average budget of EUR 2.3 million. The number of participants ranged from 9 to 38, with an average of 19. The portfolio includes a wide range of middle to large project sizes.

Table 31. Type of organisations in Case Study Marine, Source: eCorda, own calculation.

Type of organisation	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1000)	EC contribution Share (%)	EC Contr. per part. (EUR 1000)
HES	12	82	31%	32.657	36%	398,3
OTH	11	19	7%	3.288	4%	173,1
PRC	12	60	23%	18.052	20%	300,9
PUB	7	16	6%	2.931	3%	183,2
REC	14	89	33%	32.756	37%	368,0
Total (All types)	**14**	**266**	**100%**	**89.685**	**100%**	**337,2**

HES: Higher or Secondary Education Establishments

PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)

REC: Research Organisations

PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)

OTH: Other

Type of action

The sum of EC's net contribution is EUR 90 Mio, of which 37% has been allocated to research organisations, 36% to higher education institutions, 20% go private companies, 3% to public bodies and 4% to other organisations. Compared with the aggregated projects of the respective other Societal Challenge programs that relate to resources and their use in an environmentally friendly manner (SC2 to SC5), the portfolio of projects in the Marine Case Study has a larger share of funding dedicated to research organisations and higher education establishments. Additionally, the private for-profit organisations are, on average less involved and accordingly receive a lower share of funding than in any other considered SC program. As outlined, this characteristic is partly influenced by the selected project portfolio.

Table 32. Type of actions/instruments (grouped) in case study Smart City.

Group of Action/instrument	projects	Nb	Share (%)	EUR (1,000)	Share (%)	(EUR 1,000)
IA	3	61	22,9%	25.732,0	28,7%	421,8
RIA	7	160	60,2%	53.547,7	59,7%	334,7
CSA	4	45	16,9%	10.405,1	11,6%	231,2
SME	0	0	0,0%	0,0	0,0%	N/A
Other	0	0	0,0%	0,0	0,0%	N/A
All types	**14**	**266**	**100,0%**	**89.684,8**	**100,0%**	**337,2**

Source: eCorda, calculation method unknown.

The degree of application orientation is much lower than in any other SCs, with a share of 23% of project participations and 29% of funding for Innovation Action (IA). Instead, the Research Innovation Actions (RIA) are more highly represented than in any other SC. The RIA share in the marine project portfolio is 60% compared to 42% in the aggregated score of all SCs.

Within the portfolio of instruments, specific patterns of participation of actor types occur. IAs are more densely populated with private companies, whereas research organisations are rather underrepresented in this area. This relation turns into the opposite when looking at RIAs and CSAs. Public Authorities are not at all represented in Innovation Actions. In RIAs, their share is 4%. In CSAs, they are 22% of the second largest stakeholders.

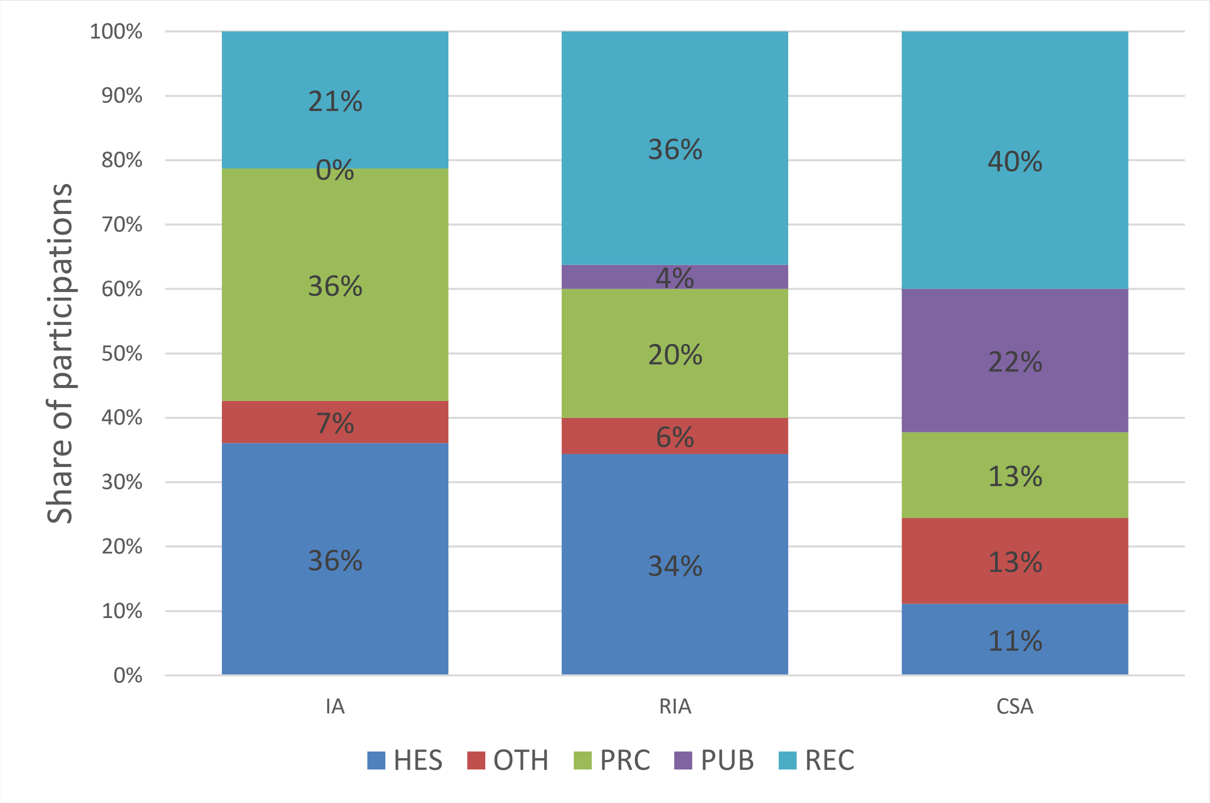

Figure 213. Share of participations by type of action/instruments.

Source: eCorda, own calculation

Table 33. Group of countries (of supported organisations) in Case Study Marine.

Group of country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Number of countries
		Nb	Share (%)	EUR (1,000)	Share (%)		
H2020-EU27	14	189	71,1%	67.697	75,5%	358,2	21
EU-14	*14*	*168*	*63,2%*	*61.310*	*68,4%*	*364,9*	*11*
EU-13	*7*	*21*	*7,9%*	*6.387*	*7,1%*	*304,1*	*10*
H2020-associated (exclude UK)	8	36	13,5%	12.322	13,7%	342,3	8
United Kingdom	10	30	11,3%	9.366	10,4%	312,2	1
Third Countries	6	11	4,1%	300	0,3%	27,3	5
All-countries	**14**	**266**	**100,0%**	**89.685**	**100,0%**	**337,2**	**35**

Table 34. Top countries (of supported organisations) in Case Study Marine.

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Order
		Nb	Share (%)	EUR (1,000)	Share (%)		
Spain	12	31	11,7%	11.881	13%	383,3	1
Italy	11	25	9,4%	7.605	8%	304,2	2
United Kingdom	10	30	11,3%	9.366	10%	312,2	3
Ireland	8	12	4,5%	4.930	5%	410,8	4
Portugal	8	14	5,3%	5.175	6%	369,7	5
Greece	8	16	6,0%	5.739	6%	358,7	6
France	8	23	8,6%	8.380	9%	364,4	7
Germany	7	17	6,4%	6.301	7%	370,7	8
Netherlands	6	10	3,8%	4.655	5%	465,5	9
Denmark	5	7	2,6%	3.109	3%	444,1	10
Sweden	5	6	2,3%	2.016	2%	335,9	11
Belgium	5	7	2,6%	1.519	2%	216,9	12
Norway	5	12	4,5%	6.181	7%	515,1	13
Malta	2	3	1,1%	292	0%	97,2	14
Canada	2	3	1,1%	0	0%	0,0	15
Romania	2	5	1,9%	2.639	3%	527,8	16
Turkey	2	11	4,1%	3.174	4%	288,6	17
Georgia	2	2	0,8%	369	0%	184,5	18
Ukraine	2	3	1,1%	650	1%	216,8	19
Bulgaria	2	6	2,3%	1.626	2%	271,0	20
Russia	2	4	1,5%	0	0%	0,0	21

Source: eCorda, own calculation.

The supported organisations participating in the 14 projects are mostly from the EU-14 countries (63 %) and the UK (11 %). Spain has the highest share of participating organizations (12 %) and EC contribution (13 %), followed by the UK, Italy and France. Third countries are represented with 4 % of project participation and – as they are in most cases not directly funded- have a very low amount of funding that comprises only 0.3 % of the EC contribution. But at least third countries participate in 6 out of 14 projects. Additionally, the inclusion of H2020-associated countries, with 14 % of participation and funding, as well as the inclusion of the UK in the project portfolio of this case study, is especially high compared to the other SCs. Only the new EU Member States (EU-13 countries) seem to be underrepresented, with a participation rate of 8 %.

Since this evaluation is about the Blue Growth part of the Horizon 2020 work programs, it makes sense to look at the representation of different marine areas when examining the composition of project participants. The organisations in countries on the Atlantic coast account for 43 % of all participations, and those with the Mediterranean coastline have an aggregated participation rate of 41 %. The North Sea is also well represented, with a 34 % share of participating organizations. The Black Sea, with 10 %, and the Baltic Sea, with 11, seem rather weakly represented. The share of EC contribution roughly equals the share of participation.

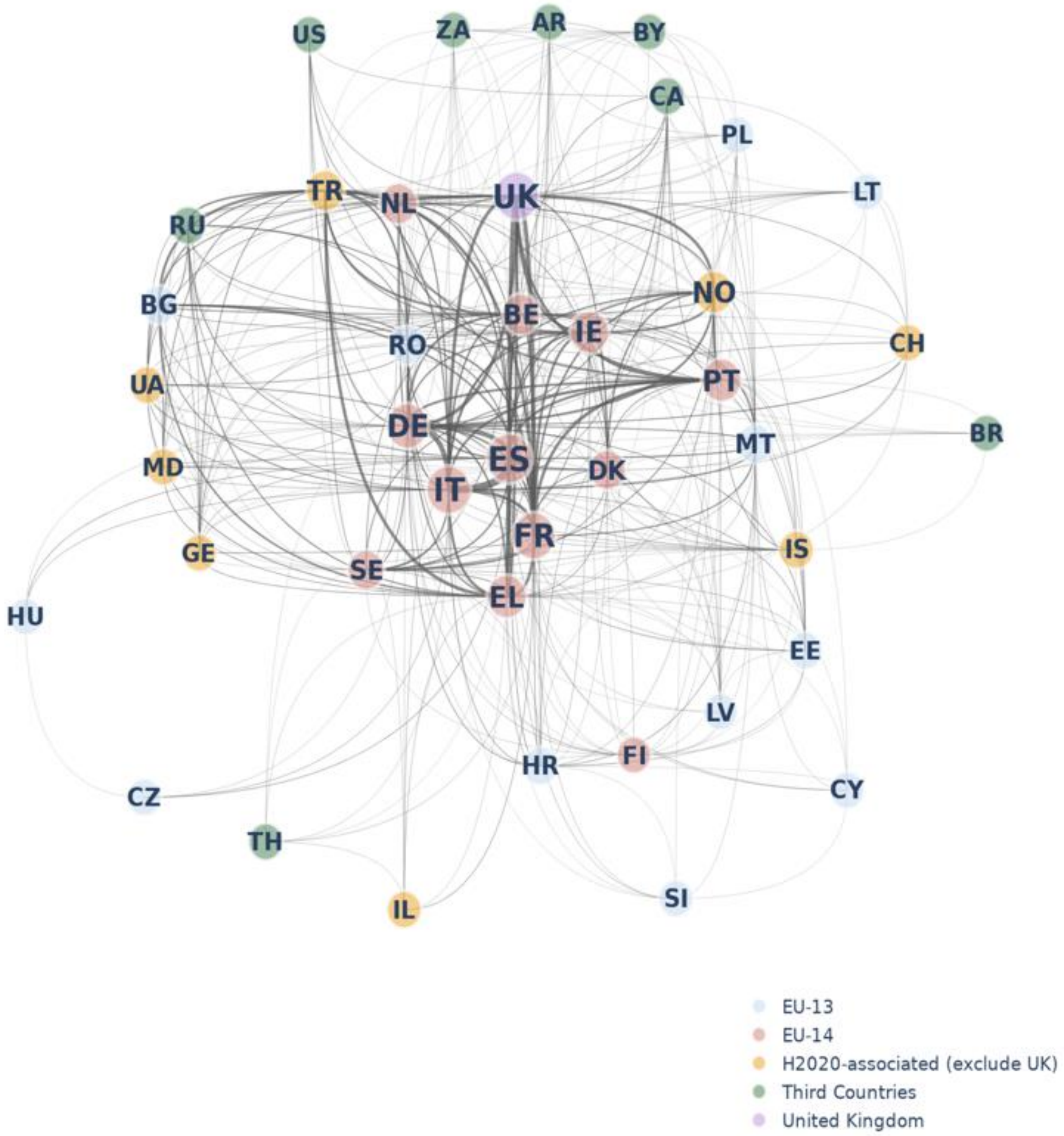

Figure 214. Network based on the number of collaborations among organisations from each pair of countries in the projects included in this case study.

The network analysis shows a high collaboration intensity among mostly EU-14 countries and the UK. The EU-13 countries, except Romania and Bulgaria, show few weak connections to other countries. The two countries are maybe somewhat outstanding because of their Black Sea coast. H2020-associated countries seem to be included in the network with many collaborations.

2.3.5. Results and outcomes of the Horizon 2020 funding activities

The portfolio analysis reveals that many projects funded under H2020 pursued multiple goals and achieved different outcomes. As some of the projects haven't been finished yet or only limited information about the achieved results and outcomes exists, the following section partially contains objectives and expected outcomes of the projects.

These can be grouped into five categories, as seen in figure 230 [75].

[75] The same categorization has been chosen as in the Intervention Logic for SC2.

Technology and Innovation	Knowledge and Capacity	Coordination and Collaboration	Market and business	Policy and standards
Selected organisms that enable new product functionalities Upscaling of promising products and processes Reduce time-to-market for innovation	Increased stock of potential substances Better understanding of policy makers and wider public about the potential of marine bioresources and raise awareness to key issues	Stronger pan-European collaboration across sea Stronger academia-industry networks International Cooperation	Identify market opportunities and develop business models Support to raise awareness and potential handling with IPR issues	Generate insights on how to best govern crucial aspects Identification of R&D&I need sand pathways (e.g. roadmaps) Specify sustainability analysis for marine products and processes

Figure 215. Outcomes of exploitation of marine bioresources in H2020.

All analysed projects addressed multiple of the five objectives shown in figure 2. The RIA and IA projects had a strong technological focus on using the sea's biodiversity. They cover the screening of enzymes and microorganisms, their extraction and, in some cases, scaling-up and cultivation of the selected ones. They address different applications and markets with food, cosmetics, health applications or bioremediation. A potential contribution also lies in faster time-to-market.

Many projects focus on business development, such as mapping and assessing different business models and activities. E.g. Maribe assesses 69 possible combinations of Blue Growth and Blue economy activities. The ERA-NET Blue Bioeconomy started different activities to support commercialization, such as planning a forum with potential investors.

Instead, explicit consumer-related or sustainability analysis has been rare in the programme's focus, and only a few projects address this explicitly (e.g. TASCMAR). The project portfolio reflects the multi-stakeholder approach mainly incorporated in the CSAs, while the RIAs and IAs addressed wider stakeholder groups via communication and dissemination.

Regarding cooperation, projects aim to pool expertise and create networks across Europe and the seas.

Many projects provided policy-relevant analysis, particularly in roadmaps (e.g. BLUEMED, Nomorfilm) or explicit recommendations for further exploitation. In addition, CSAs identify regulatory policies that must be considered for the exploitation of marine resources.

2.3.6. European Partnerships related to marine resources

In addition to the Horizon 2020 project portfolio and its related calls, various Partnerships constitute a relevant part of actions co-funded by the European Union in this case study.

The ERA-NET Cofund on Blue Bioeconomy results from a collaboration between JPI Oceans and the former ERA-NETS COFASP and ERA MBT. It consists of 27 partners from 16 countries. While the co-funded call covered four priority areas, exploring new bioresources is the most popular theme, and 13 of 19 co-funded projects relate to this topic. The use of marine waste or residues or microorganisms to recycle other wastes is highly relevant. In addition, several projects contribute to a circular bioeconomy by, e.g. exploring usages of seashell wastes or utilising zooplankton as by-products. The participation of industry is required in all projects.

The JU BBI identified marine and freshwater environments (including marine and freshwater aquaculture, fish processing industry and marine biotechnology biorefineries) as an important feedstock for producing materials. Accordingly, the partnership includes Aquatic biomass as one of the current five key types of feedstock origin. In the BBI JU, 13 projects have been funded that aim to valorise aquatic biomass, comprising 9 RIAs, 3 Demonstration IAs and one called Flagship R&I.

Finally, EIT Food supports various projects to advance the development of the EU algae sector, including food and feed supplements and products (e.g. organic milk from seaweed) from macro- and microalgae.

2.4. Synthesis of Findings related to Evaluation dimensions and Evaluation Questions

2.4.1. Effectiveness

2.4.1.1. EQ 4.1: What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results altogether leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives, and by which timeframe?

Chapter 2.3.5 presents the different dimensions of outcomes. To summarize, H2020 projects yielded many important prerequisites for achieving these goals by providing significant knowledge. The interviewees outline the results of the projects as very valuable and regard most projects as a real success in terms of results discovered, e.g. in terms of the number of promising enzymes and organisms characterized or the number of peer-reviewed publications. They have partly overachieved their own ambitions. According to the stakeholders, the FP's underlying expectation that marine ecosystems' biodiversity holds high potential for new innovative solutions for various sustainable products and processes has been proven by successful projects.

In addition, a key objective of the FP has been to move from research to commercialization. As far as information is available, many projects managed to increase TRL significantly, although not all projects reached expectations due to technical problems encountered. However, as this is usually the top line, most projects reach a maximum TRL 7, and challenges to exploiting the results on the market persist (see barriers below). In addition, the impact on the industry is partly unknown, even for the project coordinator, as large firms do not disclose dirt follow-up activities.

The project portfolio includes beneficiaries from different seas, and least in some projects, knowledge exchange across geographical areas, namely different seas, has been achieved.

2.4.1.2. EQ 4.2: Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc.) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and long term? Are there any more or less effective factors than others, and if so, what lessons can be drawn from this?

Generally, the interviewees are mostly satisfied with the implementation and do not see an urgent need for improvement. Therefore, the implemented projects and framework conditions (e.g. length of time, resources) were considered appropriate to reach the objectives.

A key success factor has been the successful pooling of knowledge from strong partners. As outlined above, sampling the huge diversity of marine bioresources is a key challenge. However, in some projects, the pooling of expertise, e.g. based on enzyme libraries and knowledge of several partners around well-defined specific research questions, was very productive. In addition, covering several stages of the innovation and value chain is important to bridge work and objectives to user needs, which was seen as an important prerequisite for further exploitation. However, the consortia must tackle known cooperation barriers in such constellations. These include finding a balance between the diverging interests of academia and industry, with the former mainly focusing on publications but less on upscaling issues, which have to be taken into account already in the early stages to provide the best-suited organisms and processes for further steps. Another challenge is the IP rights clarification. The interviewees stated that those have to be clarified beyond the expected project results, which usually end at the pilot scale level.

The interviewees pointed out the need to include non-technical aspects in the projects. They recommended that those are more explicitly asked in the calls (e.g. with an indicative percentage amount) as there are tendencies to address socio-economic aspects with a rather small share of resources to concentrate on technical issues.

Moreover, partners with the key interest and capability to implement the “solutions” in practice must be included. Therefore, it is recommended to take this as an explicit criterion next to science excellence and geographical coverage of the consortia.

Concerning barriers, the projects were affected by other crises or macro-challenges. For example, several of the projects included patterns and coordinators from the UK, so when the Brexit decision was taken, there was uncertainty in the projects regarding political Framework conditions, also, e.g. in the case of Marine Spatial Planning. Moreover, significant hurdles remain to further developing and commercialising project outcomes. These include:

- Upscaling: The interviewees point out that upscaling research laboratory discoveries that entail obtaining and maintaining the supply levels and safety requirements is a major hurdle in bringing marine natural-product-based molecules to market. Related to that, some projects are in a stage where a follow-up public-funded project appears to be the only realistic alternative.

- Legal constraints and uncertainties: various legal issues arose in the projects of the case study portfolio, such as a lack of clarity on the mechanism for benefit sharing, particularly in marine systems concerning the Nagoya Protocol.

- Consumer Acceptance: On the consumer side, there is still a lack of awareness and some reluctance to consume new products from the sea.

2.4.1.3. EQ 4.3: To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts? What further actions are needed to maximise the impact of the Framework Programme interventions in this area?

On an overall policy level, the topic has not gotten very visible. According to interviews, there was no real political urgency to put this topic further into focus. However, other maritime topics, such as the pollution of oceans, received more public attention.

On the project level, there have been intensive efforts to disseminate scientific results (see Section 6.3). Moreover, policymakers and related stakeholder groups have been addressed via non-scientific information material, presenting project findings and future policy needs (e.g. tech bottlenecks for further funding). Although the majority – but not all – interviewees are mostly satisfied with the Dissemination and Communication measures, they identified efforts to approach consumers and society.

2.4.1.4. EQ 4.4: To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The framework programme has contributed significantly to exploring and exploiting marine resources and provided important foundations for progress towards EU policy priorities and objectives related to the green transition.

The exploitation of bioresources is probably the topic in the Blue Growth Scheme with the highest direct relation to economic goals while improving sustainability or social issues not prominently incorporated in the objectives. Nevertheless, the advances in using sea resources may lead to less environmental burden and lower emissions if food further intensifies land. However, on the macro level, the question arises to what extent exploration of resources can be conducted sustainably and whether the potential extent of activities can provide significant contributions, meaning, for example, that today the contribution of aquatic resources to the bioeconomy is very marginal. Nevertheless, support activities such as MUSES set at least important foundations in Marine Spatial Planning to improve the multi-use of some selected species.

2.4.1.5. EQ 4.6: To what extent have the partnerships achieved their objectives and the objectives of the Framework Programme in this area?

The partnerships significantly contribute to leverage activities and foster international cooperation within the EU. Moreover, they complement H2020 funding by providing opportunities to build smaller and stronger focused consortia for similar topics (ERA-NET). Or in the case of BBI JU, they provide additional opportunities for the exploitation of algae, which has been mostly focused on upscaling / biorefineries in the Blue Growth topic. Similarly to H2020, the relevant partnerships have a rather high focus on integrating industries, and industry participation is either mandatory or highly recommended for projects and fulfilled in all projects.

2.4.2. EU Added Value

2.4.2.1. EQ 5.1: What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed? Could the stakeholders have implemented their research and innovation in another way, including through other national or regional support?

The funding opportunities for exploiting marine resources differ significantly in the Member States and are very low in many of them. The funding opportunities in the FP enabled the community to form new networks and to build strong consortia with partners across Europe. In addition, the EU projects enable knowledge transfer between different geographical areas and sensitization for certain topics that might be relevant to other regions. Moreover, there are topics such as marine spatial planning that are more related, e.g. to Offshore wind but might also be relevant for bioresource exploitation - that need transnational cooperation, which can be realized partly on a national research level.

2.5. Conclusion

This case study illustrates the impact of R&D funding mostly driven by socio-economic objectives – less by highly sustainability-driven research – which was characteristic of the first Work Programmes in Horizon 2020. Still, the exploitation of marine bioresources has the potential to address various SDGs.

FP funding is very important for the community to conduct R&D and build strong consortia with partners across Europe, as in many Member States, national funding opportunities are low in this area. In addition, the topic of algae is rather broadly distributed across different programmes in the FP, but current developments are underway towards a more integrated approach.

Many projects achieved significant technical and economic progress; in some projects, commercial exploitation started in or after the projects. However, well-known barriers such as upscaling, regulatory barriers for products on the market and a partial lack of consumer acceptance of new products from the sea impede market uptake. To address those barriers, the need for more interdisciplinary research, including non-technical aspects, became obvious. This can be addressed in line with the stronger explicit orientation towards Green Transition goals, which are addressed in the 2021 strategy towards a sustainable blue economy (including Algae Initiative) and the EU Mission “Restore our Ocean and Waters”.

2.6. References

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2.7. Annexe

2.7.1. Key metadata of case study no. 2 “exploitation of marine resources”

Table 35. Key metadata of case study Exploitation of Marine Resources.

Case no. 2	Exploitation of Marine Resources
Evaluation Question addressed*	Focus on: Effectiveness: 4.14.2; 4.3.; 4.4.; 4.6/ EU added value: 5.1
Area/SC	Area 1 (Food, Agriculture, Water and Bioeconomy/ Societal Challenge 2
SDGs	Life Below Water (SDG 14) but also Industry, Innovation and Infrastructure (SDG 9) and Good Health and Well-Being (SDG 3)
Programme parts	Blue Growth
Scope (no. of projects and instruments)	14 projects (RIA, IA, CSA)
Key data sources	H2020 work programmes Corda Data Project websites and Strategic documents Interviews
Links with partnerships	ERA-NET Cofund on Blue Bioeconomy, JU BBI, EIT Food
Relevant policies	Blue Growth Strategy Transforming the EU's Blue Economy for a Sustainable Future

2.7.2. Project Portfolio

Table 36. Project portfolio.

Project-ID	Acronym	Full title	Type of	CALL-ID
652677	AORAC-SA	Atlantic Ocean Research Alliance Support Action	CSA	BG-14-2014
634588	NOMORFILM	Novel marine biomolecules against biofilm. Application to medical devices.	RIA	BG-03-2014
652629	MARIBE	Marine Investment for the Blue Economy	CSA	BG-05-2014
635340	MARISURF	NOVEL, SUSTAINABLE MARINE BIO-SURFACTANT / BIO-EMULSIFIERS FOR COMMERCIAL EXPLOITATION	RIA	BG-03-2014

Project-ID	Acronym	Full title	Type of	CALL-ID
634486	INMARE	Industrial Applications of Marine Enzymes: Innovative screening and expression platforms to discover and use the functional protein diversity from the sea	IA	BG-04-2014
634674	TASCMAR	Tools And Strategies to access to original bioactive compounds from Cultivation of MARine invertebrates and associated symbionts	RIA	BG-03-2014
679849	SponGES	Deep-sea Sponge Grounds Ecosystems of the North Atlantic: an integrated approach towards their preservation and sustainable exploitation	RIA	BG-01-2015
727892	GENIALG	GENetic diversity exploitation for Innovative macro-ALGal biorefinery	IA	BG-01-2016
727874	SABANA	Sustainable Algae Biorefinery for Agriculture aNd Aquaculture	IA	BG-01-2016
727451	MUSES	Multi-Use in European Seas	CSA	BG-03-2016
727453	BLUEMED	BLUEMED	CSA	BG-13-2016
817669	MEESO	Ecologically and economically sustainable mesopelagic fisheries	RIA	LC-BG-03-2018
101000240	BRIDGE-BS	Advancing Black Sea Research and Innovation to Co-Develop Blue Growth within Resilient Ecosystems	RIA	BG-11-2020
101000518	DOORS	Developing Optimal and Open Research Support for the Black Sea (DOORS)	RIA	BG-11-2020

2.7.3. Project Objectives, outputs and outcomes

Table 37. Project Objectives, outputs and outcomes.

Acronym	Selected objectives and outcomes	Research and industrial
AORAC-SA	Transatlantic support for stakeholders (e.g. shared access to infrastructure, dissemination and knowledge transfer, and the establishment of a knowledge-sharing platform) Transatlantic coordination to identify research priorities	n.a.
NOMORFILM	Four interesting novel bioactive compounds were found (four of them showing antibiotic activity, and two of them showing anti-bio-film activity) porcine model for testing the in vivo antibacterial and antibiofilm capacity of algal molecules has been developed, validated and applied Roadmap for EU marine biotechnology resources national policies	13 peer-reviewed articles
MARIBE	assessment of 69 possible combinations of Blue Growth and Blue economy activities	n.a.

Acronym	Selected objectives and outcomes	Research and industrial
	Case studies to identify key opportunities for synergistic collaboration Mapping of Business models	
MARISURF	Development of naturally derived and eco-friendly surfactants & emulsifiers (potential markets: food, agriculture, health, textiles) Selection of bio-emulsifier (out of 570 screened substances) for larger production at the pilot plant and end-user testing	16 peer-reviewed articles
INMARE	new library of ocean-sourced enzymes: identification of 1150 enzymes, of which 1040 are available in ready-to-use expression systems Reduced time-to-market via faster enzyme screening first (bioinformatics) tools to predict promiscuity and for engineering enzymes with multiple active sites Seminars and trainings for bioinformatics, IPR issues	Four patent applications 29 peer-reviewed articles Start-up company founded
TASCMAR	Discovery of new species of invertebrates and several unique microalgal clades innovative technologies to cultivate and extract marine organisms (TRL 7) two pharmaceutical products and a cosmetic line under development intensive Communication &D Dissemination activities (e.g. 14 videos, social media activities) with the strategy to highlight the importance of finding the best compromise between the protection and exploitation of marine bioresources impact assessment, including environmental management and impact mitigation, e.g. for the protection of natural habitats;	23 peer-reviewed articles 2 patents 2 trademarks
SponGES	Tools for reporting and monitoring of indicators of sponge Vulnerable Marine Ecosystems (VMEs) 30 new sponge species and 71 microbial phyla (half of them new lineages) were discovered Different properties of sponges were discovered, and 2700 genes identified	n.a.
GENIALG	Supplying a wide diversity of chemical compounds for existing as well as new applications and markets (food, food supplements, nutraceuticals, cosmetics and personal care) Set up of two demonstrators (pre-industrial) pilot plants Implementation of derived results in the production process of participating companies	31 peer-reviewed articles
SABANA	Creation of the first fully microalgae-driven wastewater treatment (+ microalgae production) plant in Europe Evaluation of 100 different microalgae strains was evaluated for their suitability to produce the required agricultural end products Methods for characterization of microalgae/bacteria consortia analysis of social acceptance analysis through different surveys and studies	100 peer-reviewed articles Patents for microalgae-derived bio-stimulants and bio-pesticides
MUSES	Case studies engaged stakeholders to identify MU's potentiality, opportunities and limitations in strategic direction to nations around the globe seeking to develop and implement marine spatial plans and policies. Action Program details tasks for stakeholders to turn the concept of MU in European sea basins into implementation	n.a.
BLUEMED	An updated version of the SRIA Launch and implementation of four Start-up Actions assessment and mapping of relevant framework conditions enabling joint actions	n.a.

Acronym	Selected objectives and outcomes	Research and industrial
MEESO	Scientific methods for quantification of mesopelagic biota Investigation of fishing technologies to optimize catch efficiency, quality and selectivity	12 peer-reviewed articles
BRIDGE-BS	Create a connected Black Sea community assess the current state of the Black Sea ecosystems, their services, and resilience to the multi-stressors Identification of services that can support innovative business models to create added value	n.a.
DOORS	Deliver the infrastructure required to understand the Black Sea ecosystem Development of structure to support Blue Growth and the early development of start-ups Provision of evidence to shape policy in line with the Black Sea SRIA Creation of an accessible data repository	n.a.

3. Case study 3: Improving food processes and industrial value chains

3.1. Summary

Food systems are among the largest users of natural resources globally and in the European Union. According to the EIT Food, food production accounts for up to 30 % of greenhouse gas emissions worldwide, 40 % of land use and 70 % of freshwater consumption. At the same time, food systems suffer from the same sustainability challenges to which they contribute, as plummeting biodiversity threatens their resilience or as climate-change-caused droughts increase the danger of crop failure. Future-proofing our food systems and Improving food processing and industrial value chains hence constitutes a key contribution to the ambitions of the European Commission to bring about a Green Transition. One way to do so is via funding research and innovation under the umbrella of the European Framework Programmes. This study hence aims at assessing the contribution of the latest Framework Programmes to the Green Transition, notably that of Horizon 2020. In so doing, it concludes that the topic at hand is highly complex and involves a variety of heterogeneous stakeholders. This brings various difficulties, such as reconciling all stakes without compromising on the effectiveness of the Framework Programme to drive change. Nevertheless, the majority of the stakeholders interviewed for this report indicated that the European Union was generally on track. In particular, the change towards food system thinking advocated by the European Commission can be seen as promising because food system thinking better caters to complexity.

Table 40 provides an overview of the most relevant details of this case study.

Table 38. Key metadata of case study no. 3 "Improving food processing and industrial value chains."

Case no. 3	Improving food processing and industrial value chains
Evaluation Question addressed*	EQ 3.1.; 3.3.; 4.1.; 4.2.; 4.3.; 4.4.; 5.1.
Area/SC	SC 2

Case no. 3	Improving food processing and industrial value chains
SDGs	Zero Hunger (SDG 2), Industry, Innovation and Infrastructure (SDG 9), Responsible Consumption and Production (SDG 12), Good Health and Wellbeing (SDG 3), Sustainable Cities and Communities (SDG 11), Climate Action (SDG 13), Life on Land (SDG 15)
Programme parts	WP 2014/2015 (Part 9 – Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy) WP 2014/2015 (Part 12 – Climate action, environment, resource efficiency and raw materials) WP 2016/2017 (Part 9 – Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy) WP 2018/2020 (Part 9 – Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy)
Scope	13 Horizon 2020 calls Time horizon covered: 2014 – 2020. Number and type of instruments analysed: 4 RIAs, 1 CSA, and 12 IAs Number of projects analysed: 18
Key data sources	Strategic Policy Documents H2020 Work Programs & relevant call texts EIT Food Strategic Research and Innovation Agenda 2014-2021 CORDIS data Eight interviews (1 Expert, 2 Policy Officers, 5 Project Beneficiaries)
Links with partnerships/other initiatives	EIT Food
Relevant policies	Bioeconomy Strategy Circular Economy Action Plan European Green Deal Farm-to-Fork Strategy Food2030 Sustainable Development Goals

3.2. Introduction and overview

3.2.1. Objectives

The present case study identifies and analyses relevant actions concerning the topic of *Improving food processing and industrial value chains* in the Horizon 2020 (H2020) Framework Programme (FP). It does so with the intent to elucidate the extent to which H2020 activities enabled an effective approach for the topic of *Improving food processing and industrial value chains* for the Green Transition ambitions of the European Commission (EC) and to see which could be further scaled up, or improved on, under the present FP, Horizon Europe.

3.2.2. Methodology

The case study comprises multiple levels of analysis, namely

- Objective level: The analysis of policies and strategic documents setting the framework for the topic
- Input level: The analysis of H2020 Work Programmes (WP) and identification of relevant calls
- Activities level: The analysis of relevant projects funded under H2020

The analytical steps followed the structure presented in Figure 231.

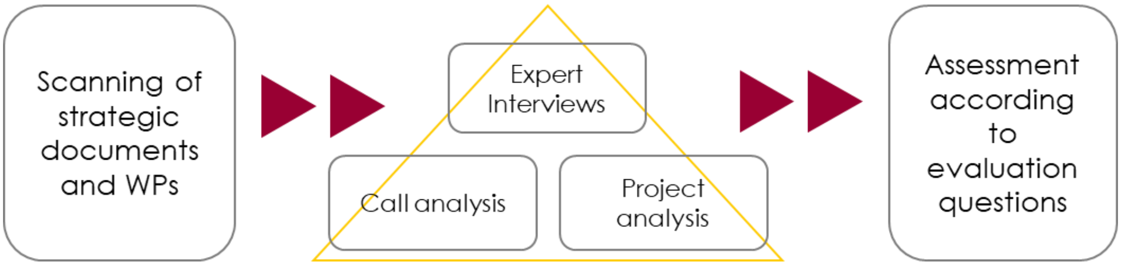

Figure 216. Analytical steps of the case study.

The scope of the case study contains projects in Societal Challenge 2 (SC2) related to the topic of *Improving food processing and industrial value chains*[76]. The analysis started with scanning strategic documents, WPs, and relevant call texts to identify the Green Transition (GT) goals concerning *improving food processing and industrial value chains*. In addition, the gathered information was used to determine a set of projects to be examined further through qualitative and quantitative analysis based on the information in the CORDIS project database. As the case study focuses on projects funded within the Societal Challenges Pillar, it omits projects from other FP pillars (e.g. SME-instrument); 18 projects remained in the sample between 2014 and 2020. The sample comprised 4 Research and innovation actions (RIAs), 12 Innovation Actions (IAs) and 1 Coordination and support action (CSA). Table 2 lists the corresponding WPs and calls, respectively.

Table 39. H2020 WPs and calls for the sampled projects.

WP 2014/2015 (Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy)	SFS-17-2014: Innovative solutions for sustainable novel food processing (komph2020-wp1415-food_en, S. 2: 3098)
WP 2014/2015 (Climate action, environment, resource efficiency and raw materials)	WASTE-2-2014: Waste: A resource to recycle, reuse and recover raw materials
WP 2016/2017 (Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy)	RUR-08-2016: Demonstration of integrated logistics centres for food and non-food applications SFS-33-2016: Understanding food value chain and network dynamics SFS-40-2017: Sweeteners and sweetness enhancers SFS-18-2017: Support to the development and implementation of FOOD 2030 - a European research and innovation policy framework for food and nutrition security SFS-35-2017: Innovative solutions for sustainable food packaging
WP 2018/2020 (Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy)	DT-SFS-14-2018: Personalized Nutrition SFS-16-2018: Towards healthier and sustainable food CE-SFS-25-2018: Integrated system innovation in valorising urban biowaste LC-SFS-17-2019: Alternative proteins for food and feed DT-SFS-26-2019: Food Cloud demonstrators RUR-07-2020: Reducing food losses and waste along the agri-food value chain

To complement the project data, the case study conducted eight interviews with relevant stakeholders, including one thematic expert, two policy officers from the European Commission, and five project beneficiaries[77]. All interviews followed a semi-structured, exploratory approach based on guidelines referencing the relevant evaluation questions (EQs), focussing on the evaluation dimensions of

[76] Due to the thematic link, the call H2020-WASTE-2-2014 from SC 5 was included in the analysis.

[77] EIT food was not available for an interview.

efficiency, effectiveness, and EU added value (see section 3). In the final step, the evaluation synthesised the relevant data to answer the EQs.

3.3. Synthesis of evidence

3.3.1. Improving food processing and industrial value chains to future-proof European food systems

Food systems are among the largest users of natural resources globally and in the European Union (EU). Food production accounts for up to 30 % of greenhouse gas emissions worldwide, 40 % of land use and 70 % of freshwater consumption[78]. For example, the EU livestock sector causes 81-86 % of the total EU agricultural greenhouse gas emissions, if one considers feed production, transport and processing[79]. In addition, importing protein feed ingredients contributes to global deforestation[80]. Moreover, whereas an estimated 20 % of the total food produced is lost or wasted, 36.2 million people cannot afford a quality meal every second day[81].

At the same time, food systems suffer from the same sustainability challenges they contribute, such as, e.g. plummeting biodiversity threatens their resilience or droughts caused by climate change increase the danger of crop failure. While the EC considers European foodstuffs already today a global standard for food that is safe, plentiful, nutritious, and of high quality, it has made clear its ambition for *food made in Europe* to also become the global standard for sustainability in the future[82].

3.3.2. Strategic policy priorities related to the topic of Improving food processing and industrial value chains

Food system challenges tend to touch many different aspects, e.g. waste, bio-based resources, and climate. Solutions hence need to involve various stakeholders, e.g., resources, interests, competencies, or level of governance. For instance, many of those to take up the solutions that FP research and innovation (R&I) projects provide are Small and medium-sized enterprises (SMEs)[83] and can thus be expected to face particularly high hurdles to transition.

Given its complexity, improving food processing and industrial value chains involves various institutional bodies. First, the EU level knows different policies and strategies that aim to future-proof our food system. The most relevant are the Food2030 Strategy, the Farm-to-Fork Strategy and the European Green Deal. Within the vision of Food2030, a list of 10 *pathways for action* has been identified as particularly relevant areas to address:

1. Governance and systemic challenges
2. Urban food system transformation
3. Food from the ocean and freshwater resources
4. Alternative Proteins and dietary shift
5. Food waste and resource efficiency
6. The Microbiome world
7. Healthy, sustainable and personalised nutrition

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8. Food safety systems of the future

9. Food systems Africa

10. Food systems and data

These ten fields provided a structured basis for R&I policy and R&I areas relevant to building up Horizon Europe and future R&I programmes in Europe and beyond. As such, they can be seen as the core objectives of the GT concerning the topic of *Improving food processing and industrial value chains*[84].

In addition to the policy domain of agriculture, food and nutrition, the topic overlaps with domains not entirely dedicated to food systems. Examples are the Bioeconomy Strategy (due to its link to bio-based resources) or the Circular Action Plant (regarding waste reduction and valorisation). By a similar token, the EU pledged itself to achieving the Sustainable Development Goals (SDGs). Those SDGs, which are particularly linked to the topic of *Improving food processing and industrial value chains,* are: *Zero Hunger* (SDG 2), *Industry, Innovation and Infrastructure* (SDG 9), *Responsible Consumption and Production* (SDG 12), *Good Health and Wellbeing* (SDG 3), *Sustainable Cities and Communities* (SDG 11), *Climate Action* (SDG 13), and *Life on Land* (SDG 15).

Lastly, while considering them would be outside the scope of the present study, there is an array of further relevant institutions beyond the above, e.g. food safety and approval regulations in the case of novel foods, data protection structures regarding the emergence of data-driven farming or Internet-of-Things technology, or the Common Agricultural Policy in the case of primary production.

3.3.3. Horizon 2020 programming related to the topic of Improving food processing and industrial value chains

3.3.3.1. R&I funding earmarked for relevant projects under FP7 and H2020

Throughout the last two FPs, the EU dedicated over EUR 18 bn to funding food system R&I. This sum equalled almost 15 % of the total EU public funding available under both FPs. In addition, Figure 232 shows that funding volumes and project numbers have increased between FP7 and H2020. Another indicator of magnitude concerning the topic of Improving food processing and industrial value chains is the share of R&I funding for projects aligned with the priorities identified by Food2030. Since its inception in 2016, the EC's Food2030 strategy intends to enable a systems approach to food-related R&I to support the accessibility of healthy, affordable and environmentally sustainable diets. It constitutes a centrepiece regarding a green transition of our food system.

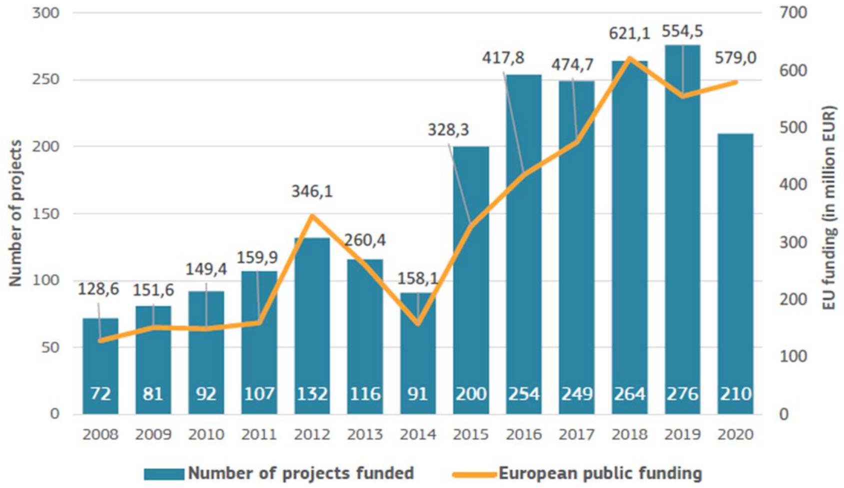

Figure 217. EU public funding for food-systems-related R&I projects, 2007-2020.

[84] The present study omitted pathways 2., 3. and 9. as they were outside the scope of this study, or are closer affiliated with other case studies.

Source: European Commission, Directorate-General for Research and Innovation, Chandler, C., Figueiredo, D., Francisco, I., Franke, J., Magalhaes, H., Mastrogregori, E., Milhazes, C., Schneuwly, S., Zanobetti, L., Goncalves, R.. FOOD SYSTEMS Research and Innovation Investment Gap Study. Publications Office, 2022, DOI 10.2777/09391

3.3.3.2. Contribution of H2020 Work Programmes towards Improving food processing and industrial value chains

The Food 2030 topics, as mentioned above, have been present in all work programmes of H2020. They are covered by SC2 ("Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy") as well as the call "H2020-WASTE-2-2014: A systems approach for the reduction, recycling and reuse of food waste" from SC5 ("Climate Action, Environment, Resource Efficiency and Raw Materials"). Throughout FP7 and H2020, the EC spent almost EUR 5 million on projects aligned with the priorities identified by Food2030.

Table 42 suggests a varying extent of coverage in terms of individual pathways. Financial data implies the same: over FP7 and H2020, the topics of *food systems and data* saw an influx of funds (7 % to 15 % of the EUR 5 million), as well as *food waste and resource efficiency* (13 % to 16 %) and *urban food system transformation* (1% to 3%). At the same time, the topic of *healthy sustainable and personalised nutrition* was lost in funding (12% to 6%), as well as *food safety system of the future* (18% to 12%) and *the microbiome world* (6% to 3%)[85].

Table 40. Project objectives of the sampled projects.

Acronym	Project Objectives	Aligned main pathway	Workpackage
FIT4FOOD2030	Establish a sustainable multi-stakeholder, multi-level platform, mobilizing a wide variety of stakeholders at the level of cities, regions, countries, and Europe to support the EC in developing and implementing the FOOD 2030 policy framework and its action plan.	Governance and systemic challenges	2016/2017
LOWINFOOD	Co-design, together with actors of the food chain, low-waste value chains by supporting the demonstration of a portfolio of innovations in the fruits & vegetables, bakery products and fish value chains, as well as in a-home and out-of-home consumption to support the reduction of food loss and waste in the EU.	Food waste and resource efficiency	2018-2020
FRESH-DEMO	Evaluate the benefits of dry mist technology and a natural acidifier to preserve and enhance the quality and freshness of fruit and vegetables along the entire post-harvest supply chain in real-scale case studies (directly after harvesting - washing step, in transportation, storage, and retail facilities).	Food waste and resource efficiency	2014/2015
i3-Food	Implement 3 prioritised innovative food processing technologies by validating optimum process control under industrial conditions: 1. Pulsed Electric Field preservation (PEF-P) of liquid food products (TRL 7-8); 2. High-pressure thermal sterilization (HPTS) (TRL 6-7) and 3. Low shear extrusion of cold food products (TRL 6).	Food safety systems of the future	2014/2015

[85] European Commission, Directorate General for Agriculture and Rural Development, Peyraud, J.-L., MacLeod, M.. How to contribute to a sustainable agricultural sector? : executive summary. Publications Office, 2020, DOI 10.2762/810306.

Acronym	Project Objectives	Aligned main pathway	Workpackage
HIPSTER	Develop and demonstrate fit-for-use knowledge, tools and industrial equipment to effectively implement High pressure and temperature processing in the food industry.	Food safety systems of the future	2014/2015
AGROinLOG	Develop and demonstrate three Integrated Biomass Logistic Centres for food and non-food products and evaluate their technical, environmental and economic feasibility.	Food waste and resource efficiency	2016/2017
YPACK	Scale up (pre-industrially) and validate two innovative food packaging solutions (thermoformed tray and flow pack bag) based on PHA, with active and passive barrier properties.	Food waste and resource efficiency	2016/2017
MYPACK	Elaborate general guidelines to select the best market for sustainable food packaging technologies and to ensure the best commercial development through (i) the best environmental efficiency (direct impacts of packaging, food waste impacts, optimized recycling composting combusting end life, preserved consumer health), (ii) the best consumer acceptability, and (iii) optimized industrial feasibility. Promote the commercial development of: 1) Biodegradable and compostable packaging, 2) Packaging from renewable resources, 3) Elaborated (high barrier and active) packaging technologies.	Food waste and resource efficiency	2016/2017
Stance4Health	Develop a complete Smart Personalised Nutrition service based on the use of mobile technologies as well as tailored food production that will optimize the gut microbiota activity and long-term consumer engagement.	Healthy, sustainable and personalised nutrition	2018-2020
WaysTUP!	Establish new value chains for urban bio-waste utilisation to produce higher-value products, including food and feed ingredients, through a multi-stakeholder approach.	Food waste and resource efficiency	2018-2020
SUSINCHAIN	Test and validate recently emerged technologies and processes aiming at a sustainable EU insect industry producing safe insect products or products from insect-fed animals, which consumers appreciate.	Alternative Proteins and dietary shift	2018-2020
SMART PROTEIN	Validate and demonstrate innovative, cost-effective and resource-efficient plant protein products from fava bean, lentil, chickpea and quinoa, as well as microbial biomass proteins created from edible fungi by upcycling side streams from pasta (pasta residues), bread (bread crust) and beer (spent yeast and malting rootlets) industries.	Alternative Proteins and dietary shift	2018-2020
FNS-Cloud	Increase the exploitation of Food and nutrition security (FNS) knowledge, contribute to reducing knowledge gaps that inhibit public health and agricultural policy, support the food industry in reducing development and production costs and increasing sustainable production, and facilitate informed and healthy choices by consumers.	Food systems and data	2018-2020

Acronym	Project Objectives	Aligned main pathway	Workpackage
REFRESH	Contribute towards the objective of reducing food waste across the EU and of maximizing the value from unavoidable food waste and packaging materials, i.a., by developing a 'Framework for Action' model that is based on strategic agreements across all stages of the supply chain (backed by Governments), delivered through collaborative working and supported by evidence-based tools to allow targeted, cost-effective interventions.	Food waste and resource efficiency	2014/2015
VALUMICS	Provide decision-makers throughout food value chains with a comprehensive suite of approaches and tools that will enable them to evaluate the impact of strategic and operational policies and enhance the resilience, integrity and sustainability of food value chains for European countries.	Governance and systemic challenges	2016/2017
SWEET	Identify and address the barriers and facilitators to using sweeteners and sweetness enhancers (S&SEs), and examine the risks and benefits of using S&SEs to replace sugar in the diet in the contexts of health, obesity, safety and sustainability.	Healthy, sustainable and personalised nutrition	2016/2017
FOX	Demonstrates and validates mobile and flexible processing units of small and medium-size companies and farmers that offer advanced technology applications for mild processing technologies (from preservation to packaging and quick quality control for healthier food production).	Food waste and resource efficiency	2018-2020
SHEALTHY	Demonstrate and validate non-thermal sanitisation, preservation and stabilisation methods to enhance the safety, preserve the nutritional quality and prolong the shelf life of minimally processed fruit and vegetable (F&V) products.	Food waste and resource efficiency	2018-2020

Overall, improving food processing and industrial value chains is not limited to these calls, as EIT Food has also funded relevant activities.

3.3.4. Analysis of Horizon 2020 project portfolio

The present study analysed a portfolio of 18 projects funded under H2020 (see the full list in Table 4 in Section 6.1)[86]. The EC's contribution to the projects ranged from about EUR 2 million to around EU 10.2 million, with an average contribution of EUR 6.2 million. The number of participants ranged from 9 to 36, with an average of 24 participating partners. Overall, the field is dominated by large project volumes and complex consortia.

3.3.5. Type of action

Error! Reference source not found.233 shows how the budget of the sampled projects is distributed over the different types of actions (right) and the three Work Programmes from 2014 to 2020 (left). The development of R&I funding for the sampled projects is congruent with the overall development of food-systems-related EU funding and project numbers from Figure 232. In addition, IAs represent the largest share in project types, measured by budget and the number of projects. This mirrors that

[86] Calls from EIT food were omitted due to the focus on data that is available in the CORDIS data bank.

Improving food processing and industrial value chains constitutes a particularly application-oriented subject.

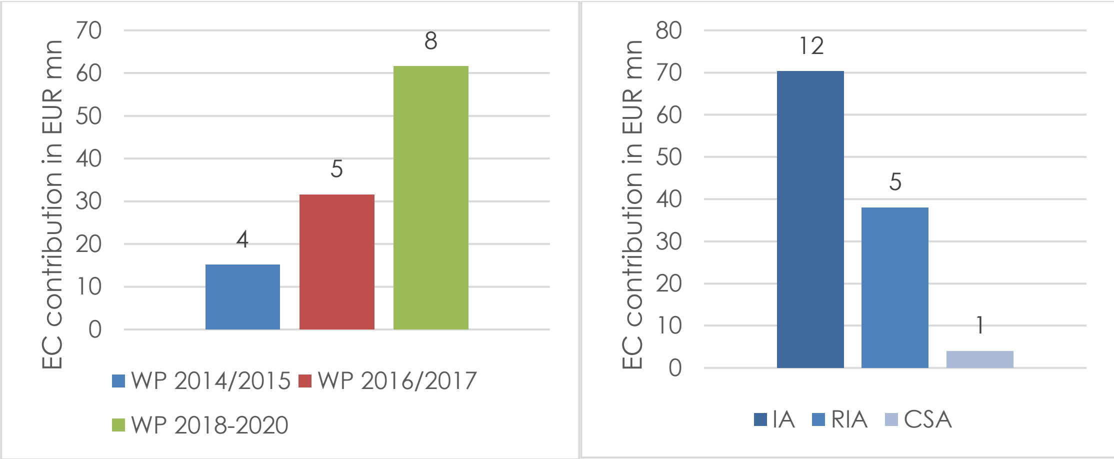

Figure 218. Left: Budget distribution over WPs. Right: Distribution of EC contribution over the type of action. Number of funded projects is indicated above bars.

Source: own calculation, based on CORDIS data

3.3.5.1. Participating organizations

Figure 234 (right) shows that Higher or Secondary Education Establishments (HES), Private-for-profit entities (PRC), and Research Organizations (REC) are the organizations benefitting most frequently from H2020 funding in the field. This indicates that different organizational entities could be well reached. However, when considering the type of action, there were clear differences, e.g. PRCs made up almost half of the beneficiaries within the IAs but only 30 % for RIAs and 0 % in the case of CSAs (Figure 234, left). By a similar token, typical research organizations, i.e. HES and RECs, profited disproportionately from EC funding: While about 46 % of participants were either HES or RECs, they received 63 % of R&I funding. Conversely, 36 % of overall funding went to PRCs and OTHs, representing 52 % of participants. Considering the importance of SMEs in the food sector, which can be expected to dispose of rather little capacities to deal with the vagaries of H2020 R&I funding, this allocation pattern seems in line with claims that the FP did not adequately cater to the need of SMEs. This seems problematic as it might discourage innovative SMEs from engaging in R&I projects.

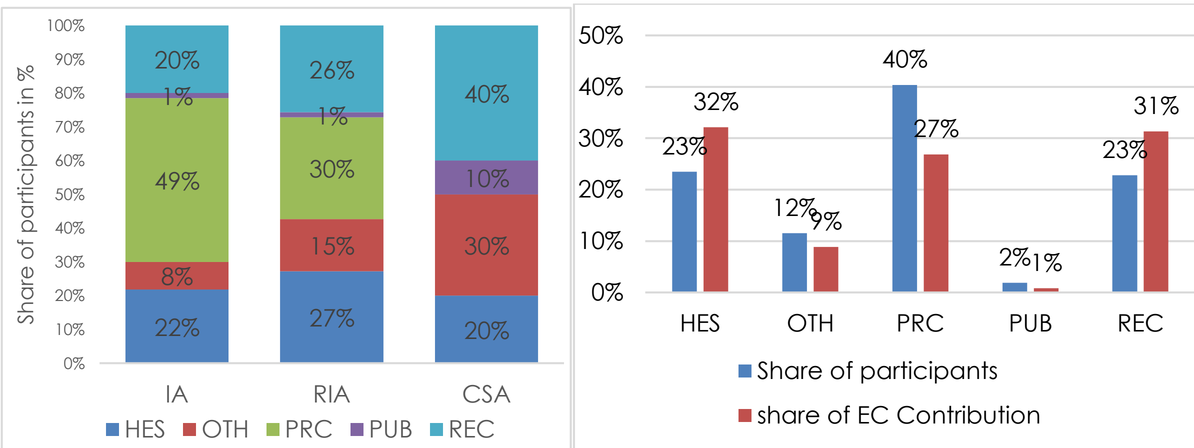

Figure 219. Participation by type of beneficiary organization. Left: Participation by type of instruments. Right: Distribution of projects and budget (EC contribution) over type of beneficiary organization.

Source: own calculation, based on CORDIS data

3.3.5.2. Participating countries and international cooperation

Among the beneficiaries, there is a strong dominance of EU-14 countries: about 97% of the EC contribution was attributed to EU-14 countries. Spain, Italy, The Netherlands, Germany, and Belgium are leading countries concerning the budget and the number of projects (**Error! Reference source**

not found. left). Conversely, Hungary and Slovenia were the only EU-13 countries to benefit, with an average of about 3% of the EC contribution. EU-13 countries were involved in fewer projects.

All 18 analysed projects were coordinated by institutions from an EU-14 country, the UK or Iceland (**Error! Reference source not found.**235 right), but none by an institution located in a new Member State. Moreover, EU-13 countries received comparatively lower budget shares per project: While there are 17 cases where a budget of at least EUR 1 million was attributed to one of the leading states, there was no case where an EU-13 country received such a high budget (based on EC contribution, data not shown).

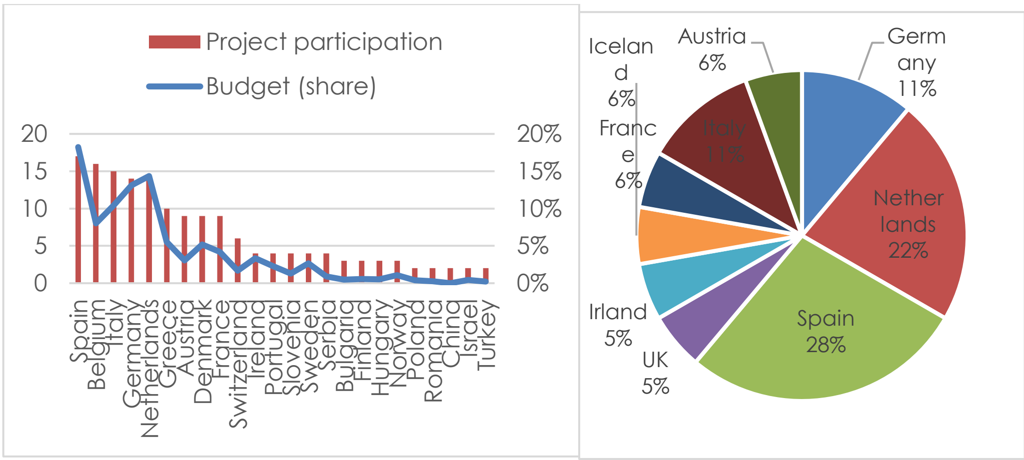

Figure 220. Left: Number of project participation by countries (bars) and share of EC budget attributed to institutions from given country (line), countries which participated in less than 2 projects omitted right: Share of project coordinating organizations according to country; own calculation, based on CORDIS data.

An analysis of the network of participant organisations (Figure 236) supports the impression that participants from new Member States and H2020-associated countries are at the fringes of R&I activities rather than their core. It also points to the fact that leading participants are particularly linked. Concerning Third Countries and countries associated with H2020, China, Israel and Turkey each feature the highest cooperation rate, with organisations from each country participating in two projects each.

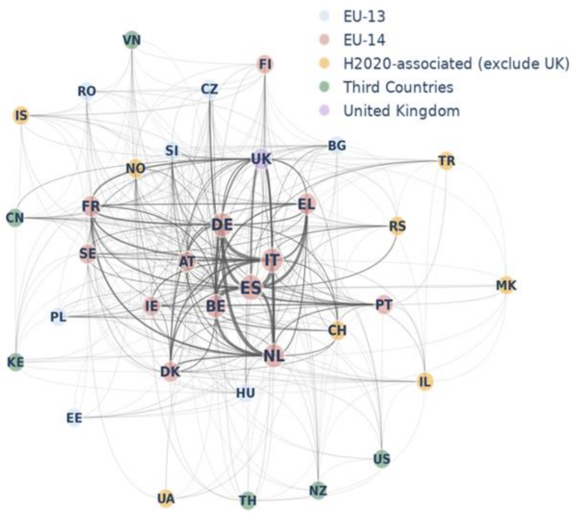

Figure 221. Network analysis on country participation for the sampled projects; own visualisation, based on CORDIS data.

3.3.5.3. Objectives and topics addressed

As Table 4 shows, all projects address at least one of the ten pathways to action from the Food 2030 framework. From a meta-perspective, the addressed objectives can be seen to fall into five overlapping categories, which are shown in Figure 7, i.e. 1) Increase the competitiveness of the EU agri-food sector, 2) Ramp up sustainable technological innovation, 3) Future-proof the EU agri-food system, 4) Empower consumers and end-users, and 5) Better govern the EU agri-food system (**Error! Reference source not found.**).

Increase the competitiveness of the agri-food sector	Ramp up sustainable technological innovation	Future-proof the EU agri-food system	Empower consumers and end-users	Better govern the EU agri-food system
Increase the competitiveness of the EU agri-food sector contribute to the success of adjacent concepts such as the bioeconomy	Advance innovative technologies to address sustainability challenges help bring innovative technologies to the market and facilitate their	Better understand the complex nature of the EU agri-food system Boost the sustainability and resilience of the EU agri-food system	consider the crucial role of consumers and end-users for socio-technological success empower consumers to make healthy food decisions	generate insights on how to best govern crucial aspects (e.g. waste and recycling, nutrition) support policy making

Figure 222. Project objectives.

Some analysed projects addressed multiple of the five objectives shown in **Error! Reference source not found.**. For example, while many projects aimed to increase the competitiveness of the agri-food sector, there was nevertheless a dedicated sustainability component, such as to advance resource efficiency of primary production systems or to provide healthier food sweetening and evidence-based policy advice (SWEET project).

3.3.5.4. Coherence and contribution to the goals of a Green Transition

As for the whole of SC2, the topic of Improving food processing and industrial value chains pursues an inclusive understanding of the GT that goes beyond the mere support of technology development or the improvement of the competitiveness of the European agri-food sector. In addition to making food production more sustainable, it integrates objectives such as fighting unhealthy diets and advancing a systemic perspective instead of a linear supply chain rationale. Especially the latter can be seen as a large contribution as it enables adequately addressing the complexity of the topic.

Therefore, overall the project portfolio is in line with the objectives of the GT and the associated strategies and policies, even though these were not in place at the time when H2020 and its WPs were designed. In addition, the growing amount of funding earmarked for food system R&I projects over the years shows that efforts have increased. Nevertheless, the financial development indicates an imbalance between different thematic areas to the advantage of primary production: While over 50 % of EU funding was allocated to primary production and food processing, only about 1 % of funding was dedicated to logistics and retail each[87]. Similarly, the lack of funding for food processing technology has remained a persistent issue. Likewise, the fact that whole streams of research may vanish when project funding ceases could be seen as an issue.

Concerning the implementation of Horizon Europe, the European Technology Platform ETP Food for Life has identified a set of R&I priorities to be addressed. These are:

- Improve the understanding of consumer behaviour

[87] European Commission, Directorate-General for Research and Innovation, Chandler, C., Figueiredo, D., Francisco, I., Franke, J., Magalhaes, H., Mastrogregori, E., Milhazes, C., Schneuwly, S., Zanobetti, L., Goncalves, R.. FOOD SYSTEMS Research and Innovation Investment Gap Study. Publications Office, 2022, DOI 10.2777/09391.

- Modularise food production and distribution together in cooperation with consumers and food retail
- Increase the knowledge of the links between food (choices) and culture
- Advance the understanding of how foods are digested
- Explore how novel ingredients affect the food matrix
- Create new primary processing and manufacturing techniques, including such that focus on the valorisation of side-streams
- Develop digitally integrated food packaging systems[88]

3.3.5.5. EIT Food

In addition to the Horizon 2020 project portfolio and related calls, the EIT Food constitutes a relevant part of the EU toolkit concerning i*mproving food processing and industrial value chains*. One interviewee remarked that EIT Food was particularly geared towards larger food companies in its work. EIT Food is a Knowledge and Innovation Community of the European Institute of Innovation and Technology (EIT). It was founded during H2020 in 2016. EIT Food aims at connecting entrepreneurs, businesses, universities, research centres, and institutes operating within the food industry across Europe to drive innovation, thereby focusing on four fields:

- Innovation: guiding and accelerating food innovation to transform the food system
- Education: empowering bright minds to lead the transformation of the food system
- Entrepreneurship: supporting agri-food entrepreneurs to deliver food innovations across Europe by building a powerful ecosystem
- Public Engagement: empower people to become agents of change in the food system [89]

From 2021 to 2027, EIT Food expects an annual budget of between EUR 68 million and EUR 95 million. Most of the latter (48 %) is to be invested in innovation, followed by ecosystem development (13 %)[90].

EIT Food has been involved in implementing Food2030, which constitutes a key strategy for i*mproving food processing and industrial value chains,* and its work intends to complement the R&I done under the FPs. The organisation aims to take up the results of projects funded by the FPs (and other sources) to support their further development and commercialisation[91]. As such, its innovation focus areas align with those from the sample of the present case study: protein diversification, circular food systems, digital traceability, sustainable agriculture, sustainable aquaculture and targeted nutrition.

3.4. Synthesis of Findings related to Evaluation dimensions and Evaluation Questions

3.4.1. Efficiency

3.4.1.1. EQ 3.1: How efficient have the implementation processes of the Framework Programme in this area been in terms of 1) administration & management, 2) project application and selection processes, 3) funding allocation, 4) forms of implementation (e.g. partnerships, collaborative research, blending, bottom-up/top-down actions)?

The data indicates that project implementation cycles were largely efficient. Nevertheless, the interviewees suggested that project application and management processes were rather complex and

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[88] ETP Food for Life. Achieving more Sustainable Food Systems through R&I: ETP 'Food for Life' Priorities for the Horizon Europe Work Programme 2023-2024. 2021.
[89] EIT Food. Website: https://www.eitfood.eu. Accessed 14.07.2022.
[90] EIT Food. EIT Food Strategic Agenda. 2021.
[91] EIT Food. EIT Food Strategic Agenda. 2018.

left room for improvement and trimming. For instance, it was pointed out that the EC project portal suffered from overload the closer application deadlines came, thus slowing down the application process for all those involved. It was furthermore remarked that the processes of adding data to the portal after the project started were cumbersome from a technical point of view, even for those who can devote more resources to them. SMEs, in particular, seem to lack the necessary resources to navigate the project administration portal. Somebody thus suggested that they could profit from some sort of hotline. Nonetheless, two beneficiaries explicitly lauded the efforts by the EC to guide them, e.g. by providing helpful templates, sticking to deadlines, or granting financial flexibility.

Furthermore, some interviewees wished for a more reflexive and transparent proposal evaluation process where (i) essential parts of successful proposals are published so that unsuccessful applicants may learn from them for the future and where (ii) it is possible to provide feedback to the reviewers, like in pee-review processes, to reduce the risk of misunderstandings. In addition, one interviewee claimed that reporting deadlines are at odds with the national holiday periods that differ between member states. This would make it hard to obtain substantial feedback from all consortium partners to incorporate in the reports.

Lastly, management efficiency seems to vary among individual cases. One interviewee, e.g. lamented that the wrap-up of their project was rather lengthy and cumbersome - but acknowledged that this was an irregular case. In addition, another interviewee claimed that grant management was partially at the discretion of the individual project officer due to a lack of rules.

3.4.1.2. EQ 3.3: What can be learned in terms of implementation processes from the experience of applicants and participants? What were the key barriers and drivers towards progress they experienced at the application stage and during the implementation of the projects, and their consequences for the researchers and organisations involved?

Overall, the interviewed beneficiaries judged the implementation process “well settled”. Nevertheless, besides the recommendations mentioned under EQ 3.1, there seems to be room for improving FP effectiveness.

First, it is important to consider that preparing proposals for voluminous projects consumes a lot of resources. What is more, the call topics were seen as so wide/generic/complex that they attracted ever more applicants while obfuscating what was actually wanted by the EC. Moreover, as the costs to prepare a proposal may amount to up to EUR 100,000 over a consortium, at a success rate of about 13 % for all H2020 programmes[92], this makes applications financial risks. The more so as basic funding for research organisations is limited and actors from the private sector are subject to rigid economic imperatives.

Since the preparation of calls, however, involves a myriad of different stakeholders beyond the leading Directorate General, with differing interests, the issue of too wide/generic/complex calls seems unsolvable for the time being. Nevertheless, one possibility to de-risk applications was to use two-step application processes even stronger. Likewise, to facilitate the participation of the private sector, funding provisions could be improved to better cater to its needs, e.g. the possibility to only work as part of a consortium for a limited amount of time. Another suggestion was to emphasise the implementation aspects of FP projects.

What is more, while the competition for funding ensures excellence, on the one hand, the rather short project runtimes do not provide enough room to adequately address societal needs in every case. That is to say, sometimes whole streams of research cease to exist when follow-up project opportunities are missing. This basically equals a waste of public money.

[92] Own calculation, undisclosed.

3.4.2. Effectiveness

3.4.2.1. EQ 4.1: What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results all together leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives, and by which timeframe?

The topic of *Improving food processing and industrial value chains* is particularly application-oriented. That is, R&I largely caters to the specific needs of the food sector and works on solutions, which are close to the market, and that companies can take up rather easily. The contribution of Horizon projects must hence be assessed in terms of their added value to the food industry. Food producers are strongly tied to the legal framework, e.g. food safety, packaging, or labelling. Therefore, what constitutes the greatest added value to them largely varies alongside legal reforms. Nevertheless, by and large, the FP seems to have delivered on the expectations.

However, one persistent criticism by the food sector regarding the FPs has been a lack of focus on food processing technologies. The EC is aware of this shortcoming and seeks to improve. The corresponding topics are rather particular and in bits and pieces, like how to keep corners clean in production lanes in a specific facility. Thus, it seems fair to say that they are difficult to incorporate in a meaningful way into R&I activities of the size of FP projects. A similar issue can be seen in the financial focus on agricultural production: under FP7 and H2020, the early stages of the value chain (primary production/food processing) received about 55 % of the funds dedicated to food-systems-related R&I[93]. While this former is an input indicator, one interviewee also remarked a weakness in impact indicators. That is, the current set of indicators does not fully capture the impact of H2020 projects on the development of the field.

Regarding the amount of time that is necessary to reach the objectives set by strategies like Food2030, the Covid19-pandemic and the war on Ukraine could lead to an increase, as they have enforced a shift in focus (and possibly in resources) (see Section 3.2.2).

3.4.2.2. EQ 4.2: Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc.) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and longer term? Are there any factors that are more or less effective than others, and if so, what lessons can be drawn from this?

Overall, the interviews indicated the generally large importance of developments on a macro-political level for project progress. For instance, one interviewee mentioned that they had "addressed the right topic at the right time". By a similar token, if project run times were not perfectly synchronized with corresponding policy processes and needs, it may have decreased project impacts.

The most significant forces to influence the development of FP interventions regarding the topic of *Improving food processing and industrial value chains* were the Covid19 pandemic and the Russian war on Ukraine. While strategies such as Food2030 put a sustainability transition of the European food system centre stage, the double crisis has abruptly propelled more immediate questions to the centre of attention instead, most notably that of food security. Moreover, detrimental second-order effects of the crisis compel immediate policy attention as well. For instance, the rising inflation lowers consumer purchasing power, which in turn threatens especially organic farmers, which produce at higher costs but also (mostly) at a higher level of sustainability. In the worst case, the double crisis might translate into a shift in R&I funding at some point away from long-term goals like sustainability towards short-term ambitions such as securing food security by all means. Yet, even if the crisis was to cease all of a sudden, it stands to assume that it nonetheless leaves its mark on R&I programming.

The double crisis also significantly affected progress on the project level. Most obviously, many activities had to be switched to the virtual space (e.g. stakeholder meetings, midterm review). While this seems to have largely gone well, researchers nonetheless lament the foregone opportunities that are more likely to result from in-person interaction. One beneficiary also mentioned that the rapidly

[93] European Commission, Directorate-General for Research and Innovation, Chandler, C., Figueiredo, D., Francisco, I., Franke, J., Magalhaes, H., Mastrogregori, E., Milhazes, C., Schneuwly, S., Zanobetti, L., Goncalves, R.. FOOD SYSTEMS Research and Innovation Investment Gap Study. Publications Office, 2022, DOI 10.2777/09391.

rising costs in the aftermath of the war on Ukraine had become prohibitive for some of the planned technological project components. On the upside, some projects saw an increase in public attention. Moreover, the accessibility of online activities may have increased project reach in some cases.

3.4.2.3. EQ 4.3: To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts? What further actions are needed to maximise the impact of the Framework Programme interventions in this area?

The interviewed beneficiaries highlighted the success of their dissemination and communication measures. The recommendations that can be derived from their success are:

- projects should maximize the interactiveness of their activities in order to raise the attention and the interest of relevant stakeholder groups (e.g. it does not suffice to upload reports on the project website)
- activities should be tailored to the needs of the target audience, e.g. take the form of webinars on concrete topics
- projects should seek to synchronize with sister projects in order to amplify each other's messages
- work cycles should be synchronised between scientific and dissemination, and communication work packages to ascertain that there is something to be presented
- the EC should continuously monitor whether project consortia show the necessary level of ambition when it comes to the dissemination and communication of work packages over the project runtime
- EC-hosted communication and dissemination events should be flanked by more activities to raise awareness among target stakeholder groups

While projects under the topic of *Improving food processing and industrial value chains* are application-oriented, the interviews nevertheless indicated that it was difficult the facilitate exploitation as this generally outstripped the resources of R&I projects. Or, they did not see R&I projects as being responsible for facilitating exploitation to start with. The EC has indeed already installed mechanisms to ex-post boost the solutions found under FP projects. These may, however, profit from increasing awareness among project beneficiaries of their existence in order to maximize momentum.

3.4.2.4. EQ 4.4: To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The topic of *Improving food processing and industrial value chains* is deemed intrinsically interwoven with a variety of different EU policy priorities as well as with an array of SDGs. Any success of H2020 is therefore seen to pay on them by default. Some projects claimed to have contributed to concrete policy processes.

In addition, interviewees lauded how H2020 has contributed to two changes in dominant R&I project paradigms. First, FP has helped to put food system thinking higher on the agenda. Allowing this change away from a linear value chain has paved the way towards embracing the complexity of the food sector. Second, H2020 has aided in raising awareness for the value of involving a variety of stakeholders in R&I activities via multi-actor approaches. It has thereby contributed to making research more interdisciplinary and thus increasing its value for end users.

Nevertheless, there remains a caveat when it comes to assessing the exact size of the impacts of H2020 on the development of the field due to the broad scope of the addressed sub-topics and because of the inaccuracy of existing indicators.

Likewise, the setting up of the project call mirrors the variety of different stakeholders and interests involved. While this seems natural from a policy point of view, this compromise nature makes it harder to discern the trajectory of progress from an evaluation angle. Moreover, the involvement of a variety of different stakeholders may prove challenging to the EU's sustainability ambitions if the former's interests diverge too far from each other.

3.4.3. EU Added Value

3.4.3.1. EQ 5.1: What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed? Could the stakeholders have implemented their research and innovation in another way, including through other national or regional support?

While it provides jobs to about 4.5 million people, the European food and beverage sector does not even invest 1% of its turnover in research and development (R&D)[94]. This indicates a general need for public R&D investments regarding the topic of *Improving food processing and industrial value chains*. The added value of the latter becomes even more pronounced when including the farming sector, whose socio-economic structure is even more detrimental to great R&D efforts than that of the SME-heavy food processing industry.

In addition, as has been laid-out above, the complexity of the topic of *Improving food processing and industrial value chains* makes governance difficult. Moreover, R&I funding by EU Member States - which is driven by national considerations - significantly surpasses that by the EU, as the comparison of Figures 2 and 8 reveals. While these bottom-up activities are seen as valuable, a major added value of the FPs is to provide some sort of coherence of R&I activities regarding the most relevant objectives, which are outside the immediate interests of the Member States. Since the EU is responsible for regulating a large part of food production, the FPs thus allow conducting R&I from a perspective that matches that of policy making.

Figure 223. Number of projects and national public funding on food systems R&I 2007-2020 (million EUR).

Source: European Commission, Directorate-General for Research and Innovation, Chandler, C., Figueiredo, D., Francisco, I., Franke, J., Magalhaes, H., Mastrogregori, E., Milhazes, C., Schneuwly, S., Zanobetti, L., Goncalves, R.. FOOD SYSTEMS Research and Innovation Investment Gap Study. Publications Office, 2022, DOI 10.2777/09391

What is more, one interviewee mentioned that the thinking in food systems was way more pronounced at the EU than at the national level. Given the complexity of the challenges, however, systemic thinking may prove particularly beneficial to address them. On a similar line, some of the interviewees suggested that another added value of H2020 projects was to bring together a variety of diverse stakeholders, which can have benefits as “Everyone sees the elephant in the room differently”. In so doing, the Horizon FPs enable the emergence of R&I networks on a European scale and increase interaction between different levels of government.

3.5. Conclusion

The present case study holds four major conclusions. First, it found no particular indications for grave concerns about how the FP delivered on its expectations and, thus, the GT ambitions of the EC. Second, it highlights the importance of the subject. The list of events and developments outside the influence of the EU which threaten its existence has increased ever more speedily. The Covid19 pandemic and the Ukraine crisis have only been the most recent crises to show the public the need to significantly ramp up the transition of the European food system towards a more sustainable, more resilient, and more just version of itself.

Third, due to their ad-hoc character, crises, as the before-mentioned, bear the danger of shifting political priorities in favour of existential, yet short-term, results. Those involved in developing further Horizon Europe are thus well-advised not to lose sight of long-term GT goals like sustainability.

[94] Own calculation based on FoodDrink Europe. Data & Trends EU Food & Drink Industry 2021 edition.

Fourth, the case study shows the complex nature of the subject, which covers sub-topics as diverse as, e.g. sustainable packaging, alternative proteins, or efficient food logistics, and which must cater to the needs of a sector dominated by SMEs. This high complexity could diminish the effectiveness of EU R&I interventions as it may add to the watering-down tendency of extant institutional structures and dynamics, e.g. as it increases the circle of stakeholders to involve in the creation of project calls or exercises. Balancing diverging needs and interests without compromising on the sustainability motives of the field or on the effectiveness of FP interventions thus constitutes another main challenge for decision-makers.

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3.7. Annexe

3.7.1. Horizon 2020 project portfolio

Table 41. Horizon 2020 project portfolio.

Project-ID	Acronym	Full title	Type of action	CALL-ID	Work package
774088	FIT4FOOD2030	Fostering Integration and Transformation for FOOD 2030	CSA	H2020-SFS-2017-1	2016/2017
101000439	LOWINFOOD	Multi-actor design of low-waste food value chains through the demonstration of innovative solutions to reduce food loss and waste	IA	H2020-RUR-2020-1	2018-2020
634699	FRESH-DEMO	Waste reduction and quality improvement of fruits and vegetables via an innovative and energy-efficient humidification/disinfection technology	IA	H2020-SFS-2014-2	2014/2015

Project-ID	Acronym	Full title	Type of action	CALL-ID	Work package
635478	i3-Food	Process integration for rapid implementation of sustainable innovative food processing	IA	H2020-SFS-2014-2	2014/2015
635643	HIPSTER	Deployment of high pressure and temperature food processing for sustainable, safe and nutritious foods with fresh-like quality	IA	H2020-SFS-2014-2	2014/2015
727961	AGROinLOG	Demonstration of innovative integrated biomass logistics centres for the Agro-industry sector in Europe	IA	H2020-RUR-2016-1	2016/2017
773872	YPACK	HIGH PERFORMANCE POLYHYDROXYALKANOATES BASED PACKAGING TO MINIMISE FOOD WASTE	IA	H2020-SFS-2017-1	2016/2017
774265	MYPACK	Best markets for the exploitation of innovative sustainable food packaging solutions	IA	H2020-SFS-2017-1	2016/2017
816303	Stance4Health	Smart Technologies for personAlised Nutrition and Consumer Engagement	IA	H2020-SFS-2018-1	2018-2020
818308	WaysTUP!	Value chains for disruptive transformation of urban biowaste into biobased products in the city context	IA	H2020-SFS-2018-1	2018-2020
861976	SUSINCHAIN	SUStainable INsect CHAIN	IA	H2020-SFS-2019-1	2018-2020
862957	SMART PROTEIN	Smart Protein for a Changing World. Future-proof alternative terrestrial protein sources for human nutrition encouraging environment regeneration, processing feasibility and consumer trust and acceptance	IA	H2020-SFS-2019-1	2018-2020
863059	FNS-Cloud	Food Nutrition Security Cloud	IA	H2020-SFS-2019-1	2018-2020
641933	REFRESH	Resource Efficient Food and dRink for the Entire Supply cHain	RIA	H2020-WASTE-2-2014	2014/2015
727243	VALUMICS	Understanding food value chains and network dynamics	RIA	H2020-SFS-2016-2	2016/2017
774293	SWEET	Sweeteners and sweetness enhancers: Impact on health, obesity, safety and sustainability	RIA	H2020-SFS-2017-2	2016/2017

Project-ID	Acronym	Full title	Type of action	CALL-ID	Work package
817683	FOX	Innovative down-scaled FOod processing in a boX	RIA	H2020-SFS-2018-2	2018-2020
817936	SHEALTHY	Non-Thermal physical technologies to preserve fresh and minimally processed fruit and vegetables	RIA	H2020-SFS-2018-2	2018-2020

4. Case study 4: Sustainable and smart cities and communities

4.1. Summary

The case study identifies and analyses relevant actions related to smart and sustainable cities and communities in Horizon 2020 and respective partnerships (i.e. JPI Urban Europe and linked ERA-NETs). The thematic scope of the case study comprises areas of 1) Urban Mobility and Transport, 2) City Buildings, 3) and City Energy Systems.

The case study shows that the work programs have established a portfolio of interventions in the smart and sustainable cities field which provided important foundations for progress towards EU policy priorities and objectives related to the green transition. The case study shows that the FP contributed to a) novel integrated socio-technical solutions to the challenges associated with a green transition and b) important enabling conditions for expediting a green transition across a wider range of countries across and beyond Europe. We identified six main enabling factors for the effectiveness of the portfolio, 1) focus on innovation, 2) increased visibility through implementation, 3) focus on replication and upscaling, 4) integration of system solutions, 5) involvement of challenge owner and demand side and 6) creating a community of practice. Furthermore, the FP shows that the leader/follower pairing provides effective mechanisms for matching stakeholders with shared interest, shared challenges or challenges owners with solution providers. In this vein, the platform "Smart Cities Marketplace" provided more targeted and thus effective measures in supporting the replication and upscaling of project results, whereas the public-public partnerships in this area also contributed to the formation of national research and innovation communities as well as need owners at the city level.

4.2. Introduction and overview

The case study identifies and analyses relevant actions related to smart and sustainable cities and communities in Horizon 2020 and respective partnerships (i.e. JPI Urban Europe and linked ERA-NETs). It provides an assessment of the implementation of the Horizon 2020 funded projects in this area and shows how the results and outcomes contribute to the overarching goals of Horizon 2020 and whether Horizon 2020 provided a strong basis for developing and progressing the Horizon Europe Mission on Climate Neutral and Smart Cities. Against this background, the main objective of this case study is to analyse to which extent Horizon 2020 actions enabled an effective approach for creating sustainable cities and communities that can be further scaled up in Horizon Europe.

The analysis comprised 12 Horizon 2020 topics & 5 JPI Urban Europe Calls (ERA NETS). The time horizon covered with the analysis is 2014 – 2020. The number and type of instruments analyzed are 5 RIAs, 2 CSAs, 5IAs and 5 ERA NETS. An overview is provided in the Annex of this case study.

The analytical approach (Figure 1) commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to Smart and Sustainable Cities and Communities (e.g., Set Plan Strategic Plan, Set Plan 3.2 Implementation Plan, SRIA JPI Urban Europe). We then identified relevant project actions in Horizon 2020 based on a key-word search of topics in the work programme and an analysis of the information portal of JPI Urban Europe. For the identified projects, relevant data as available from Cordis/Corda have been compiled and analyzed and complemented by additional sources like project websites.

In addition to the project data analysis, we performed six expert interviews. The interviewees comprised representatives of thematic experts involved in the European strategic processes, representatives of JPI Urban Europe, project beneficiaries and city innovation experts. The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus.

For synthesizing the analysis, we triangulated and analyzed the findings in relation to the evaluation questions.

4.3. Synthesis of evidence

4.3.1. A green transition in cities

Cities are key players in the global fight against climate change, as they have an enormous footprint by consuming over 65% of the world's energy and accounting for 60%-80% of global CO_2 emissions, depending on the estimates[95]. In Europe, cities take up only 4% of the EU's land area, but they are home to 75% of EU citizens.

The main sources of GHG emissions in European cities are **buildings** (36%), **transport of goods and persons** (35%), **production and consumption of goods and services**, including food and the provision of **energy** and other utilities (in total 29%)[96]. Due to de-industrialisation, the larger part of GHG emissions for goods and services consumed in Europe are generated in other parts of the world, namely 85%[97].

As outlined in the preparatory actions of the design process of the European Mission on Climate Neutral and Smart Cities, **pathways towards climate neutrality of European Cities** require shaping the transformation process of domains that have a high impact on current and future emission levels. Particularly relevant areas are 1) Urban Mobility and Transport, 2) City Buildings, 3) and City Energy Systems. Therein, technology alone will not solve any of a city's challenges. According to the expert report, pursuing pathways towards climate neutrality will require a co-evolvement of technological and social innovations, knowledge capacity building within city authorities and businesses, large-scale public and private investments in physical infrastructures and buildings, new business models and services that induce a behavioural change of actors, and incentive systems and regulative actions at the national level. For all domains, digitalisation is deemed as a technological enabler, for which scarce evidence suggests that digital technologies could help to reduce global carbon emissions by up to 15% – or one-third of the 50% reduction required by 2030.

4.3.2. Strategic policy priorities related to a green transition of cities

Against the background of the strategic importance of cities in the fight for climate neutrality and just and sustainable development, several high-level international and European policy strategies have been developed in order to facilitate a green transition of cities[98].

The most prominent ones at the international level are: 1) the United Nations Human Settlement Programme (UN-HABITAT) (housing and sustainable urban development) and the New Urban Agenda, 2) the 2030 Agenda for Sustainable Development Goals (SDG 11) stressing the overarching target to make cities inclusive, resilient and sustainable, and 3) the Global Covenant of Mayors strategies for Climate & Energy.

At the European level, the European Urban Agenda (Pact of Amsterdam, May 2016) set up a new multi-level working method promoting cooperation between Member States and within the Juncker Plan, the European Fund for Strategic Investment (EFSI) funded energy efficiency projects that shall

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[95] See: https://unric.org/en/sdg-11/, page visited on 22.04.2022
[96] European Commission, Directorate-General for Research and Innovation, Borsboom, J., Haindlmaier, G., Dinges, M., et al., Mission area : climate-neutral and smart cities : foresight on demand brief in support of the Horizon Europe mission board, Publications Office, 2021, https://data.europa.eu/doi/10.2777/123417
[97] Ibid.
[98] For a summary of these policies, please see Annex A.3

"support projects promoted by cities and local governments" in priority[99]. Within the European SET-Plan (Action n3.2) from 2016 the Working Group 3.2 developed an integrative approach to Positive Energy Districts (PED) in 2018, including technological, spatial, regulatory, financial, legal, environmental, social and economic perspectives, which was integrative considered in the Strategic Research and Innovation Actions of JPI Urban Europe and related ERA-NET calls[100]. Today, as part of the Green Deal[101] (2019), the Climate Neutral and Smart City Mission is a cornerstone of a green European City Strategy, going beyond the targets of the SET-Plan. Related to cities, the EC Green Deal stresses that 1) transport should become drastically less polluting, especially in cities, 2) the biodiversity strategy will also include proposals to green European cities and increase biodiversity in urban spaces, 3) the proposed European Urban Initiative[102] shall provide assistance to cities…to develop sustainable urban development strategies, and 4) that the EU Covenant of Mayors will continue to be a central force to provide assistance to cities and regions that want to commit to ambitious pledges on climate and energy policies.

Summarising, the overall ambition of the existing high-level policy strategies related to a green transition of cities, is to raise the **quality of life** in European cities (citizens as end-users) and progress towards a more **sustainable, resilient and liveable urban development** (in the nexus of economic-social-environmental issues). Cities aim to contribute to the Green Deal target of reducing emissions by 55% by 2030 and, in more practical terms, to offer cleaner air, safer transport and less congestion and noise to their citizens. The design of the EU Mission to deliver 100 Climate Neutral and Smart Cities by 2030 highlights the relevance and the ambition for delivering a green transition of European cities.

This quest for cities that are more vibrant and resilient hubs of economic and social activity whilst **minimising unintended social and environmental consequences** is characterised by the ambition to **reduce greenhouse gas emissions of cities**, increase the **resilience to climate change**, and minimise the dependency on **resources**.

Throughout the strategic documents analysed, the necessity of a collaborative approach that strengthens cities', industry and user capacities in its effort to combat climate change and increase liveability is mentioned. Notably, these key urban policy strategies were developed during the runtime of Horizon 2020, which had to align actively with the new policy developments in the area.

4.3.3. Horizon 2020 programming related to Sustainable and Smart Cities

4.3.3.1. Horizon 2020 Work Programmes related to Sustainable and Smart Cities

Sustainable and Smart Cities objectives have been present in all three biannual work programmes of Horizon 2020 in different programme parts (mainly SC3 Energy, SC5 Climate).

The calls analysed across the program parts with the umbrella term "Climate" focus on pollution reduction and environmental protection. More specifically, pollution reduction relates to air pollution, water pollution and noise pollution. Linked to pollution reduction were health benefits to citizens and improvements to their quality of life. The smart and sustainable cities, called under the umbrella term "Energy", had a stronger focus on increasing the share of renewable energy and associated reduction in greenhouse gas emissions. Additionally, energy efficiency gains were central and linked to cost reduction of energy production and consumption as well as job creation or resource efficiency more generally.

The Work Programme 2014-2015 noted that sustainable development of urban areas requires new, efficient, and user-friendly **technologies and services, in particular in areas of energy, transport and ICT, delivered through** integrated approaches at the level of research and development and deployment[103]. It stressed the need for validation of new business cases and financing models, **standardisation, scalability and replicability of the solutions**, user acceptance and engagement in technological-driven developments with a **high market potential**. Smart, ICT-based solutions and

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[99] See: https://energy-cities.eu/juncker-plan-european-parliament-decides-to-support-local-energy-efficiency-projects/
[100] See: https://jpi-urbaneurope.eu/wp-content/uploads/2021/10/setplan_smartcities_implementationplan-2.pdf
[101] See: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52019DC0640&from=EN
[102] See: https://futurium.ec.europa.eu/en/urban-agenda

[103] See: https://ec.europa.eu/research/participants/portal4/doc/call/h2020/common/1617601-part_1_introduction_v2.0_en.pdf

contributions to (technical) standardisation have been at the core, whereas a clear focus on climate neutrality has not yet been fully developed. The European Innovation Partnership on Smart Cities and Communities should aim at large-scale commercial roll out by transferring solutions to cities and communities with similar constraints.

The work programme 2016-2017 aimed at improving urban socio-economic functioning through sustainable integrated energy and transport solutions and to develop business models, innovative financing modalities and appropriate governance modes for integrated solutions[104]. The focus was on **large-scale demonstration** projects as **'living laboratories'** for deployment, testing, replication and scaling up of innovative systemic and yet locally attuned solutions aiming to help make the EU a **world leader in a new market for sustainable energy solutions**.

The work programme 2018-2020 constitutes a bridging between Horizon 2020 and Horizon Europe, in which innovative solutions for sustainable cities are being seen as also a cross-cutting concern[105]. Reducing the **carbon footprint** of cities and improving the **efficiency of the energy system** moved to the core of the work programme, and aspects addressed under areas such as governance, planning, citizen engagement, boosting equal opportunities, promoting social integration and community building were strengthened. The work programme within the energy section focused on **cost reduction and performance improvements** of a broad portfolio of renewable technologies and their integration into the energy system. Improved energy efficiency in buildings (contributing to the decarbonisation of the EU building stock by 2050) has been a key technological target.

Throughout the three work programmes, not only technological development but integration of efforts and collaboration between public and private stakeholders at national and regional/city levels have been stressed. The inherent ambition of the H2020 work programme related to urban matters was to 1) enable the creation of European sustainable city strategies and 2) provide the necessary conditions for the emergence of related innovation ecosystems, and 3) create a more integrated European market for sustainability solutions for cities.

In programming terms, this was reflected by the **deployment of the Smart-City lighthouse approach** and the creation of the **Scalable Cities Initiative**[106]**.** Therein, the marketplace aimed to promote solutions and business models that can be scaled up and replicated across Europe and aim to lead to measurable outcomes such as new jobs and energy savings. While ICT and the conceptualisation of 'Smart Cities' had a stand-alone character in the early phases of Horizon 2020, the focus on climate neutrality, sustainability and target-oriented capacity building moved to the fore.

4.3.3.2. Summary of strategic policy priorities

Against today's strategic priority to develop climate-neutral and smart cities, already Horizon 2020 and its Work Programmes aimed to contribute to a green transition. The analysis of the Work Programmes and the projects showed that distinct pathways to impact can be identified that connect the activities carried out within the work programme with identifiable effects (outcomes). Based upon the Work Programme analysis, Figure 239 provides an overview of pathways to impact identified in the analysis of the city case.

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[104] See: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-intro_en.pdf
[105] See: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-intro_en.pdf
[106] https://smart-cities-marketplace.ec.europa.eu/scalable-cities

Coordination & Collaboration	Knowledge & Capacity	Market & Business	Technology & Innovation	Policy & Standards
• Double/tripple Helix • International Partners • City to City • Project to Project	• New & Synthesized Knowledge • Learning & Training • Monitoring & Evaluation	• Pilots & Demonstrations • Replication & Upscaling • User Involvement • Cost Benefit Accounting • Business Models and Plans • Crowding-in Funding	• Improved Sectoral Services • Open Data & Transparency • Risk Reduction • System Integration	• Policy • Regulatory Frameworks

Figure 224 Expected Outcomes across all analysed calls.

The **coordination and collaboration** pathway highlights the increasing importance of collaboration between different stakeholders (from researchers to city authorities and companies implementing changes in the city), research disciplines and geographical extent. In the city context, the ambition was to facilitate trans-disciplinary collaborations between different types of stakeholders through city-to-city, project-to-project, and international cooperation actions.

The **knowledge and capacity building** pathway relates, on the one hand, to the need to develop new knowledge and methods as well as frameworks for the systematization of data and enabling decision support. On the other hand, the need for dedicated capacity building & training activities amongst different target stakeholder groups is underscored. Likewise, monitoring and evaluation for the development of new city indicators and establishing learning frameworks for improving decision-making support and city governance also played an integral part.

The **market & business** pathway emphasizes greater involvement of public and private actors and a focus on pilot and demonstration activities to test solutions in practice and to follow a need and demand-driven approach. The marketability and feasibility of solutions should be supported to generate interest among market actors. Demonstration and pilot activities should facilitate replication, upscaling, and new business models.

The **technology and innovation** pathway emphasizes the importance of improving sectoral services in cities by means of developing integrated technology solutions. This involves the deployment of a portfolio of solutions as part of a new system or their deployment and integration into an existing system with associated improvements in the services that these sectors provide.

The **policy and standards** pathway emphasizes, on the one hand, the need to facilitate better urban planning and better institutional governance arrangements (e.g. multi-level, cross-sectoral, cross-system). On the other hand, new technical standards and standard-setting measures are needed for building interoperable technology city infrastructure(s) and process frameworks for sustainable and smart cities.

4.3.4. Project portfolio characteristics

4.3.4.1. Horizon 2020 project portfolio

The project portfolio of this case study comprises 40 projects, of which 19 projects are just about to finish in 2022. The sum of EC's net contribution is EUR 538 Mio, of which 33% has been allocated to private companies, 25% to public bodies, 16% to research organisations, 15% to higher education institutions and 11% to other organisations. Compared with all other Green Transition areas considered in this study (SC2 to SC5), the portfolio of city projects has the highest share of funding for public bodies (25% in the case study vs 5% in all Green Transition areas and other organisations (11% vs 6%), indicating a particularly high relevance for municipalities and regional actors (agencies, civil society representatives etc.) taking part in the calls.

Table 42. Type of actions/instruments (grouped) in case study Smart City.

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1000)
		Nb	Share (%)	EUR (1000)	Share (%)	
HES	39	201	16%	81.384	15%	404,9
OTH	39	163	13%	60.821	11%	373,1
PRC	39	461	36%	176.295	33%	382,4
PUB	39	267	21%	135.669	25%	508,1
REC	40	181	14%	83.821	16%	463,1
Total (All types)	**40**	**1273**	**100%**	**537.989**	**100%**	**422,6**

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

Source: eCorda, own elaboration

With a 78% share of funding allocated to Innovation Actions (IA), the city case study portfolio is characterised by a high degree of application orientation and a limited representation of CSAs compared with the aggregated Green Transition project portfolio, in which the share of IA is at 47,3% and the share of CSA at 7,4% of allocated funding. The portfolio highlights commitment to the pathway of innovation and commercialisation of research results, which have also been confirmed in the interviews. Within the portfolio of instruments, specific patterns of participation of actor types occur. IAs are more densely populated with private companies, whereas RIAs have a considerably higher share of participation in Higher Education Institutions (HES) and Research Organisations (REC). Public Authorities are represented in all instruments.

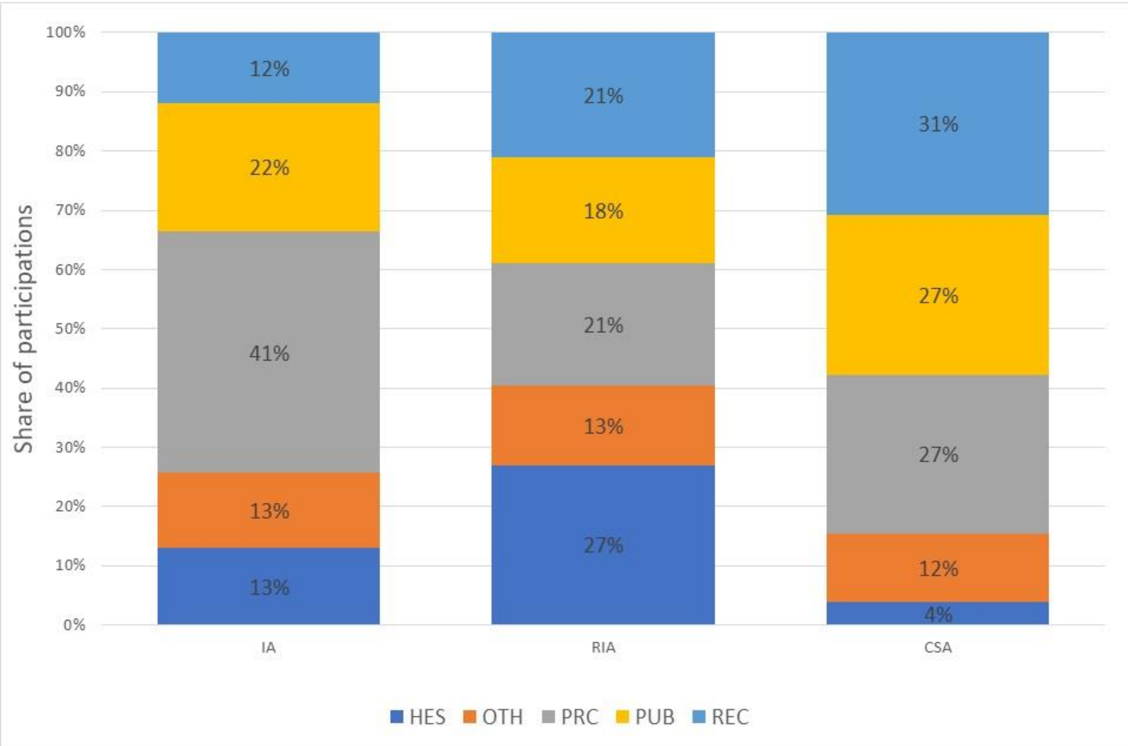

Figure 225 Share (%) of participations by type of action/instruments.

Source: eCorda, own elaboration

Table 43. Group of countries of the case study sustainable and smart cities.

Group of country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Number of countries
H2020-EU27	40	1 048	82,3%	448 589	83,4%	428,0	26
EU-14	*40*	*927*	*72,8%*	*417 958*	*77,7%*	*450,9*	*14*
EU-13	*37*	*121*	*9,5%*	*30 631*	*5,7%*	*253,2*	*12*
H2020-associated (exclude UK)	26	89	7,0%	44 946	8,4%	505,0	12
United Kingdom	24	67	5,3%	39 870	7,4%	595,1	1
Third Countries	18	69	5,4%	4 585	0,9%	66,4	18
All-countries	**40**	**1 273**	**100,0%**	**537 989**	**100,0%**	**422,6**	**57**

Source: eCorda, own calculation

Geographically, the eCorda statistics show that Horizon 2020 opened up the participation of associated countries and third countries. Associated countries (excluding the UK) have participated in 26 out of 40 projects, and third countries in 18 out of 40 projects. However, the total budget for this group represents only 9.3% of all EU contributions. The largest gap in terms of participation in relation to EC contribution is observed for the EU-13 countries, which participated in 37 projects but received only 5.7 % of the total budget. This is, however, at an equal level with all Horizon 2020 Green Transition projects.

In terms of participation pattern, the Netherlands stand out with the highest share of EC contribution in total funding (17%) and in absolute funding per participant, followed by Spain (13%) and Germany (12%) with lower EC contribution but a higher number of participations.

The participation pattern sees countries and cities that pursue ambitious climate neutrality targets and early adopters of the Smart City concepts in Europe (e.g. Amsterdam) at the forefront. On the downside, a low rate of participation rate of EU-13 indicates a high level of exclusiveness that might be detrimental to utilise the full transformation potential across Europe.

Table 44. Top countries in the case study Sustainable and Smart City.

Top 15 country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Order
Spain	34	176	13,8%	69 054	13%	392,4	1
Germany	33	130	10,2%	64 583	12%	496,8	2
Italy	31	107	8,4%	36 157	7%	337,9	3
United Kingdom	24	67	5,3%	39 870	7%	595,1	4
Belgium	24	43	3,4%	15 725	3%	365,7	5
Netherlands	22	115	9,0%	92 009	17%	800,1	6
France	18	92	7,2%	27 513	5%	299,1	7
Austria	16	21	1,6%	5 220	1%	248,6	8
Finland	14	66	5,2%	34 052	6%	515,9	9
Sweden	14	55	4,3%	24 115	4%	438,4	10
China	12	23	1,8%	0	0%	0,0	11
Poland	11	22	1,7%	5 905	1%	268,4	12
Denmark	11	21	1,6%	7 880	1%	375,2	13
Portugal	11	31	2,4%	12 593	2%	406,2	14
Greece	11	38	3,0%	13 929	3%	366,6	15

Source: eCorda, own calculation

The network analysis based on the number of collaborations among organisations from each pair of countries in the projects included in this case study confirms that the sustainable case study shows a high collaboration intensity among a number of core countries, predominantly from the EU-14, collaborating to a large extent among themselves.

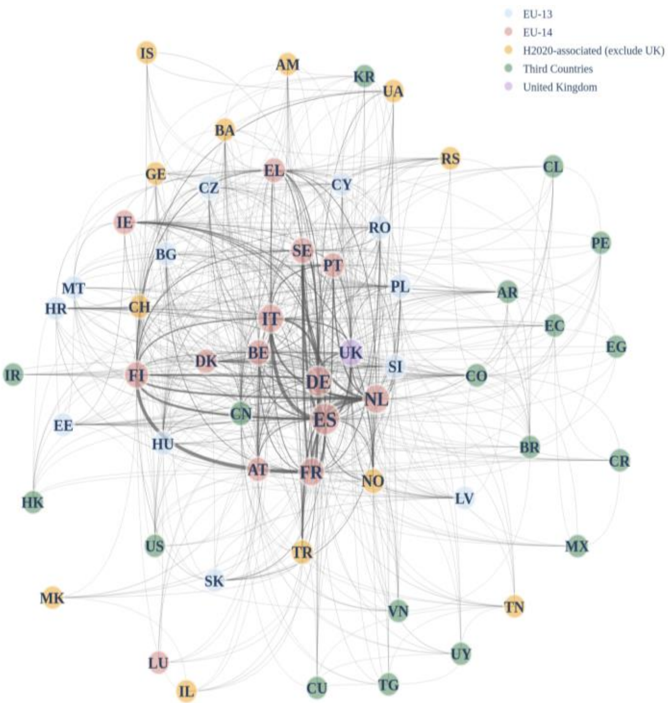

Figure 226 Network of participating countries in Case Study Smart City.

Source: eCorda, own calculation

4.3.4.2. European Partnerships related to Sustainable and Smart Cities

In addition to the Horizon 2020 project portfolio and its related calls, ERA-NET CoFunds under the framework of the Joint Programming Initiative Urban Europe constitutes a relevant part of actions co-funded by the European Union in this case study.

Under the umbrella of JPI Urban Europe, JPI Urban Europe has launched annual calls addressing specific areas and priorities in the Strategic Research and Innovation Agenda of JPI Urban Europe. ERA-NET Cofunds included 1) Smart Cities and Communities (ENSCC, 01/2016-05/2020), 2) Smart Urban Futures (ENSUF, 01/2017 – 03/2021), 3) Urban Accessibility and Connectivity (ENUAC, 01/2021 – 05/2024), and 4) The Sustainable Urbanisation Global Initiative (SUGI)/Food-Water-Energy Nexus (01/2018 – 05/2022)[107].

62 projects amounting to a total budget of Mio. EUR 77,4 have been funded in the four ERA-NET Calls, i.e. 14% of the funding volume of Horizon 2020 projects in this case study. Compared with the Horizon 2020 projects, the ERA-NET Cofunds exhibit a distinct higher share of participation of universities (49% vs 16%) and lower shares of business participation (19% vs 36%) as well as city municipalities and other government organisations (12% vs 21%).

JPI Urban Europe followed a multi-faceted challenge-driven approach addressing complex issues and wicked challenges (urban dilemmas) to provide sustainable urban solutions and enhance knowledge, research capacity and impact of research on urban transitions[108]. It is not a programme that relies on a technology push but one that is built on the idea that the people in need in the city are the ones with whom you have to work and whose needs you have to address. Instead of a technology-driven approach, the emphasis was on 1) inter- and transdisciplinary research to improve the understanding of how socially, economically and environmentally sustainable European urban areas are and 2) the creation of new knowledge and concepts to tackle urban challenges.

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[107] See Annex A3 – Overview on ERA-NETs funded in relation to the Case study topic.
[108] See: https://jpi-urbaneurope.eu/calls/intro/

Coordination and collaboration, in particular with EU-MS, city stakeholders, other strategic initiatives and networks, international cooperation and widening participation was a key focus. In terms of project funding activities, JPI Urban Europe calls aimed to:

- **Co-create ideas, concepts and solution**s, reflect the latest developments and support mutual learning to better meet societal and urban needs;
- **Create room for experimentation, share experiences, jointly test new approaches and create references** for their own programmes;
- Foster sharing resources, including integrated **urban models, datasets, urban observatories and urban living labs;**
- Develop the **understanding, knowledge, tools and evidence** to underpin the formulation of effective urban transition policies and strategies and **contribute sociotechnical innovation** to this end;
- **Explore new data sources, and big data for monitoring and evaluation**, providing a framework to monitor and assess sustainability.

4.3.4.3. Results of the Horizon 2020 funding activities: pathways to impact

4.3.4.4. Coordination & Collaboration Pathway

Coordination and collaboration between different types of stakeholders (from researchers to city authorities and companies implementing changes in the city), research disciplines and geographical extent played a considerable role in the portfolio. In particular, the lighthouse projects followed the logic of linking different cities in terms of socio-economic determinants, size and geographical variety to address a wider range of challenges and needs across Europe.

Secondly, the work programmes highlight coordination within the Framework Programme between the different calls and ongoing projects in order to follow up activities and create synergies.

"Collaboration is key" - Project beneficiary of one lighthouse project

The important role of collaboration is well recognized in the project portfolio. In the cases, the analysed projects created learning platforms that connect cities, businesses and research institutions and universities (Triple Helix). Especially in those cities where many public services are privatized, the work programs aimed for the involvement of all relevant market participants (large industries as well as SMEs) as well as relevant city stakeholders in the project consortium in order to 1) jointly develop solutions and improve the knowledge and capacity of system-actors, 2) implement and adopt solutions by relevant market participants, and 3) create a policy and regulatory framework that enables technological standards. To this end, projects developed and employed a variety of co-creation tools and approaches to engage the Triple Helix stakeholders. The data analysis supports this argument and shows that the EC contribution is highest for public institutions, followed by an equal share for private actors, research institutions and higher education institutions (see above).

The interviewees highlighted that the feasibility and strength of a project depend largely on the diversity of actors within the consortium, which needs to be composed already at the proposal writing stage before funding. In this way, the project can ensure from the start that the solutions are co-developed and implemented in the city. It was emphasized that a project consortium needs to work very closely together, build trustful relationships in order to be successful in implementing solutions and following them up. The following example highlights the challenges when a business is not involved from the beginning of the process:

“In the city of Rotterdam, they had done a feasibility study for a cooling network […], it could be done with a fairly good business case. But then the network operators simply said, “I'm not interested”. […] So, the city was left with empty hands, even though it was a fairly good business case. (City Innovation System Expert)

In addition, interviewees highlighted that one important success factor of projects is that the problem owner - in this case, the city - is the project leader. Reasons for success could be the closer focus on problem orientation, a higher probability of implementation of the solutions (rather than a focus on the deliverables of the project) and a stronger connection to policy makers in the city. Furthermore, it was acknowledged that citizens are becoming more central for successful project implementation as they see this as a component of building legitimacy, trust, and recognition, as well as developing solutions based on citizens' needs.

In terms of cooperation between projects, a representative of the European Commission noted that clusters (e.g. Smart Cities Marketplace) between lighthouse projects have become very strong networks. Even completed projects continue to exchange, which is a necessary condition for the future of the Framework Programme in order to maintain close coordination between projects.

“And I think this is something that should be incorporated in the future, always, directly from the beginning, as an idea that you're not just throwing out one separate project and letting it swim or drown by itself. But that you really say, you, over the years, you are building up a cluster of similar ones that are incrementally building on what the first ones did” (EC Representative)

4.3.4.5. Knowledge & Capacity Building Pathway

The projects analysed produced actionable, factual, and practical knowledge on various facets of smart and sustainable cities, such as the integration of energy technologies into the energy system of a city or the integration of innovative solutions (e.g. nature-based solutions) with a view on the governance and institutional framework conditions. Related outputs were found in the form of scientific publications, policy briefs to inform decision-makers, publicly available reports, as well as webinars and e-learning events that were accessible to the different target audiences of a project.

Knowledge sharing was enabled through dedicated liaison groups set up to enable peer-to-peer exchange and liaison with city representatives or other project partners from the academic or private sectors. These groups were often formed around specific topics of interest or shared challenges and led to the formation of a community of practices in the smart and sustainable cities and communities field. Clearly, the collaboration between city stakeholders (e.g. local governments) with research institutions has enabled the translation of research results and their adaptation to the cities’ context. Beneficiaries interviewed welcomed this exchange which is highlighted in the following statement:

“But we have to connect the cities’ knowledge to other knowledge from laws, research institutes and universities, which is essential in this project - a city alone cannot do this”. (Project beneficiary of one lighthouse project)

Transdisciplinary research and the emphasis on co-creation through living lab approaches ensured that also lay persons' perspectives (e.g. citizens) were taken up, further enriching knowledge co-production with experts and users. Furthermore, the projects often co-produced new knowledge in an interdisciplinary way involving natural science, engineering and social sciences.

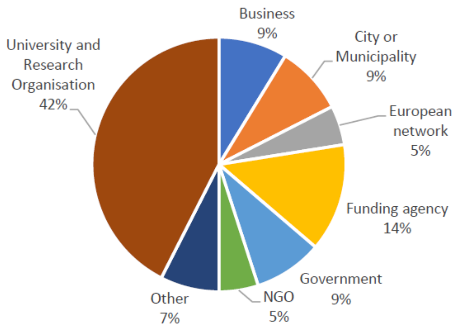


Figure 227 Participating stakeholder groups at AGORA.

Exceeding the project level, within the framework of the co-funded ERA-Nets and JPI Urban Europe, the AGORA stakeholder platform[109] provided a collaboration space for urban stakeholders with diverse backgrounds (researchers, practitioners, public administrators, planners, entrepreneurs, social innovators, and more.) to meet, exchange, identify and discuss priorities, and work together on the most pressing urban challenges of today and the future. The AGORA aims to translate knowledge between different stakeholder communities and bring them together for mutual learning. On the one hand, the stakeholder communities represent urban communities of practice (e.g. urban research, citizen organizations, city authorities, business, public utility providers), and on the other hand, they are policy communities of practice (e.g. R&I policy makers and programmers and urban policy makers).

This is reflected in the participation of stakeholder groups in the AGORA platform. The majority of AGORA participants are affiliated with universities or research organizations, followed by funding agencies (Figure 242). 133 Cities have participated in events organized by the JPI Urban Europe between 2014-6/2018. 9% out of a total of 1281 participants over all events have been from cities (city authorities, city agencies, regions, and networks of cities within a region). Two AGORA events took place from 2017-06/2018, having cities as the main target group.

At the level of Research, the JPI Urban Europe Research Alliance (UERA) brought together research-performing organisations and aims to strengthen, expand and optimise coordination activities and research planning in Europe in order to avoid fragmentation and optimise resources in the field of urban research and innovation capabilities. Currently, UERA brings together 58 European research organizations from 20 different countries. Activities of the UERA comprised[110]:

- presentation of calls and matchmaking events, including EU Horizon 2020 calls (7),
- one UERA conference (2021) - Transforming Urban Governance in a Post-Pandemic World and two UERA summer schools,
- activities (e.g. surveys, conference sessions, call for papers) and multiple events (brainstorming meetings, seminars, webinars) of the UERA working groups on Economy and Welfare (2), Environmental Sustainability (3), Smart and Sustainable Cities (7), Governance and Participation (2), Accessibility and Connectivity (3).

While these activities are suitable measures for enhancing the strategic capacity of European R&I actors working on urban sustainability topics, joint capacity building and strategic coordination between Horizon 2020 activities and the activities of JPI Urban Europe (and related ERA-NETs) was restricted to an informal exchange between EC officials and Urban Europe representatives on call topics that have been selected, leading to limited room for synergies concerning the strategic orientation of the project portfolio and/or joint activities related to the acceleration of uptake and diffusion.

4.3.4.6. Market & Business Pathway

The market & business pathway emphasizes greater involvement of public and private actors that is well reflected in the participation pattern of the projects. Projects funded in the work programs focused on the visibility and implementation of real-world solutions through a focus on pilot and demonstration activities to test solutions in practice and the development of *new* business models and plans. The design of the Lighthouse Projects instrument aligned with this idea of thinking by bringing Leader and Follower cities together to enable learning and exchange between different cities with the aim to contribute to the replication and upscaling of integrated solutions. Lead cities can showcase potential solutions which are then adapted in other cities. To enable inspiration and change mindsets within the follower cities, one informant stressed the importance of creating a common vision, strategy and roadmap within the lighthouse project. Another crucial aspect of such projects are ambassadors, committed people who take on the spirit and drive of implementation having the relevant networks and channels to accelerate change.

[109] See: https://jpi-urbaneurope.eu/agora/
[110] See: https://jpi-urbaneurope.eu/uera/uera-activities/

Replication success stories highlighted the importance of proximity between cities. As part of the Sharing Cities project, Greenwich - a London borough - has implemented several activities to create a business model for e-bike sharing, install PV panels and educate citizens about energy spikes, and was the first London borough with a smart city strategy. These activities have inspired other London boroughs, which have learned from Greenwich and its strategic planning and implementation. In another case, Rotterdam has shared the experience at the district level by also involving the smaller surrounding cities, which are normally not in a position not only to apply for these projects but also to develop smart city strategies. All these activities have not been directly funded by the European Commission but emerged as a result of an exchange of experiences related to the geographical proximity and networks of the cities. As project beneficiaries sometimes do not have the capacity to participate fully in such exchanges, it was highlighted that such learning activities should be promoted by providing funding to the regional cities surrounding the lighthouse cities.

Several barriers and challenges in the area of market integration and creating new markets have been detected. When projects come to an end, incentives to work vanish as funding sources for the 'last mile' do not exist. To counter this, one expert stressed that projects with high chances for market impact should be provided with more innovation-oriented follow-up funding. In regard to creating new markets, respondents stressed that this currently goes beyond the scope of such projects. What they can do, however, is to create *collaborative* business models that involve key actors in developing a city's mission towards carbon neutrality. In addition, one of the interviewees said that "replication is not in a city's DNA", emphasizing that the nature of cities is often to manage but not to create innovative new strategies with the potential to replicate. Moreover, it is often difficult for cities to involve companies in developing solutions because of conflicts of interest. While a city is interested in finding the right solution for its specific context, companies often look for business cases with high replication potential and positive economies of scale. Respondents report that it is often easier to work with city-owned companies, as this circumvents the conflict of interests.

To counterbalance this challenge and increase changes for replication, the Smart Cities Marketplace (SCM) provides a platform for investors showcasing use cases from more than 80 successful European projects, including 18 Lighthouse projects, thereby comprising activities from more than 120 small and medium-sized towns as well as metropolises. As such, it pools knowledge from demonstration activities within the projects to "identify and promote solutions and business models that can be scaled up and replicated across Europe" (Website Scaleable Cities). This initiative also aims to counterbalance this by demonstrating that some solutions implemented in one city can also work in other contexts to incentivize businesses to invest (see quote below). The SMC currently features 6 action clusters (Citizen Focus, Integrated Planning, Policy and Regulation, Sustainable Built Environment, Sustainable Urban Mobility, Integrated Infrastructures and Processes, Business Models and Finance) with more than 23 initiatives. Across all clusters, the SCM received 123 bankable solutions. Currently, the SCM comprises a network of 982 active members from cities administration, industries, SMEs, researchers and other smart city actors. Importantly the SCM community also consisted of 17 investors and was able to attract 585 million in investment (Smart City Marketplace Website).

All projects feature on the SCM follow a self-reporting procedure. The data obtained between 2010 – 2020 indicate some trends in key smart and sustainable cities metrics. Most notably, total energy consumption, as well as primary energy demand in refurbished buildings, was reduced while the share of local renewable energy in new as well as refurbished buildings increased. Overall, the CO2 emissions in new and refurbished building stock have been reduced (Smart City Marketplace Website).

4.3.4.7. Technology & Innovation Pathway

The projects in the work programs focused on improving sectoral services in cities by means of providing integrated technology solutions. This involved the deployment of a portfolio of solutions as part of a new system or their deployment and integration into an existing system and improvements in the services that these sectors provide. In the transport sector, emphasis was placed on the speed, fluidity, safety and connectivity of transport services. For urban water management services, aspects of water availability, water quality improvements as well as water hazard management (e.g. flooding) were stressed. In relation to energy services, aspects of energy security and reliability were underscored. Across all of these services, aspects of sustainability, carbon neutrality, and equity were important considerations throughout the work programs.

Moreover, open data & transparency was an important feature of this pathway. This involved the interoperability of data structures and frameworks, notably for the purposes of enabling the adaptation of innovative solutions for other contexts or by other actors as well as ease of replication. In this regard, the avoidance of vendor or customer lock-in was emphasized, as well as the reduction of entry barriers and the accessibility of data more generally. Additionally, ICT tools and services for system improvements (e.g. energy, transport, water) was consistently highlighted.

Many projects developed and implemented solutions with a higher TRL level. This points to a stronger focus on applied research, rather than basic research, in the work program, which is also reflected in the participation and involvement of private sector stakeholders in a number of projects. Importantly, this collaboration supports the development of solutions that match the commercialization requirements of private sector stakeholders, thereby enabling market integration, replication and upscaling beyond the boundaries of the projects. Whilst higher TRL levels were prominent in the work program and the project analyzed, technological openness in the exploration of solutions was an equally important facet. The following summarizes a number of integrated technology solutions developed by projects in the smart and sustainable cities and communities field:

- Batteries and photovoltaics for renewable energy production and storage in urban areas.
- Integrated photovoltaics applied to the existing building stock in urban areas
- Energy Communities as new forms of organizing renewable electricity production and consumption in cities.
- Positive energy districts for sustainable, resilient and decentralized energy production and consumption at the district level.
- Retrofitting building envelopes in terms of improving their energy efficiency and thus supporting energy savings in urban areas.
- Decarbonized and efficient district heating and cooling networks in urban areas
- Heat pump-driven district heating systems for decarbonizing the energy system and improving air quality in cities.
- Electric vehicles in cities and associated requirements for the electricity infrastructure in cities.
- Electric buses as part of the decarbonization of the public transport fleet in cities
- Sustainable modes of urban freight logistics and associated technology solutions for the last mile.
- Green and blue infrastructure solutions for climate adaptation and improvements to the livability of cities.

4.3.4.8. Policy & Standards Pathway

The ambition to contribute to improved policy making involved activities geared towards the provision of better urban and land use planning policies as well as new or better institutional and governance arrangements[111]. Addressing regulatory Frameworks involved better compliance with EU and national regulation (e.g. EU Air Quality), contributions to improvements of existing regulatory frameworks as well as new standards and norms.

While there has been a certain alignment in terms of the definition of strategic topics for concrete ERA-NETs within the Framework of JPI Urban Europe, there was a notion of limited strategic dialogue for aligning the Horizon 2020 Work Programme(s) and the activities of the Urban Europe Initiative. The strategic research agendas that have been developed by the JPI have not been co-created in dialogue

[111] For example multi-level, cross sectoral, cross system governance models and contribution to overarching policies (e.g. Urban Agenda) or the development of of new instruments (e.g. CCC).

with the EC; only very broad rounds of discussion between DG RTD, but also CLIMA, MOVE and ENER and EAC took place.

At the project level, the analysis of the project summaries showed a high degree of alignment with a number of SDGs (11, 3, 1, 7, 9) with a specific focus on increasing the resilience and adaptive capacity of cities to extreme weather events and on improving the health and well-being of citizens, with an emphasis on the most affected poor population.

At a more operational level, standardization of data and platforms has played a considerable role in Horizon 2020, and the interviews also stressed that attention and funding to these topics should be sustained. For holistic city development approaches, the requirement of developing standardized platforms and interfaces that enable system integration not only on a project basis but also at a system level, dealing with the interfaces of housing, energy, and mobility could further contribute to the integration of already existing technologies and improve city planning.

4.4. Conclusion

To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The work programs have established a portfolio of interventions in the smart and sustainable cities field which provided important foundations for progress towards EU policy priorities and objectives related to the green transition. Each of the pathways identified in this case study has contributed to this portfolio through a) novel integrated socio-technical solutions to the challenges associated with a green transition and b) important enabling conditions for expediting a green transition. Taken together, this portfolio provides a highly valuable basis that can be built on by Horizon Europe initiatives such as the Climate Neutral Cities Mission or the Partnership Driving Urban Transition (DUT).

Further strengthening the portfolio by developing systemic solutions which target the social and cultural conditions in which technology is embedded will be key. While the focus on higher TRL levels in the work programs was valuable, it is important to also develop social or institutional innovations which cannot be based on TRL assessments alone.

Which internal or external factors (such as access to specific stakeholder groups, change of understanding of ‘innovation processes’ etc.) have influenced the progress or lack of progress of the Framework Programme interventions in this area towards their impact?

This case study identified a set of six factors for establishing an effective portfolio. These were present across all pathways.

1. Focus on applied research: This involved solutions with a higher TRL level as well as a stronger involvement of industry and private sector partners.

2. Increased visibility through implementation: Increased visibility of integrated solutions (pilots and demonstrations) reduced perceived risks (technological and/or financial) and improved learning on the practicalities of implementation.

3. Focus on replication & upscaling: The Leader-Follower logic enabled learning and exchange on the most relevant issues for replicating solutions, and the involvement of the private sector/industry facilitated market integration, thus upscaling.

4. Integration of system solution: The multi-system or nexus approaches directed attention to the interfaces of systems and sectors as well as the interfaces of social and technical solutions.

5. Involvement of challenge owner and demand side: Involving urban stakeholders, in particular local government and citizens, ensured the development of solutions that match their needs and improved ownership and thus uptake.

6. Creating a “community of practice”: Community building across projects through, e.g., the Smart Cities Marketplace enabled learning from each other and building on each other’s results.

To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts?

Effective mechanisms for communication and dissemination support the capitalization on the investment made by the work programs. This case study identified a number of mechanisms, from project to program level, for improving communication & dissemination measures for impact. First, at the project level, coaching and capacity building of project stakeholders helped to improve the effectiveness of their individual project communication activities beyond traditional scientific channels and audiences. Second, communication and dissemination were effective in resolving tensions with stakeholders related to implementing solutions (e.g. tenants or interest groups) when used early in the project or even before it started. Third, at the program level, communication and dissemination measures were particularly effective when they addressed the specific needs of a particular stakeholder group. Twinning and leader/follower pairing provide effective mechanisms for matching stakeholders with shared interest, shared challenges or challenges owners with solution providers. On this basis, communication & dissemination measures were more targeted and thus effective in supporting the replication and upscaling of project results. Fourth, pursuing strategic partnerships with multiplier organisations who have established thematic networks (e.g. ERRIN, ICLEI) was beneficial to improve outreach. Such partnerships were also critical with regard to national R&I stakeholders, who are most effective in communicating through appropriate national channels, further improving outreach.

To what extent has international cooperation and, more specifically, association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme?

International cooperation with third countries was an important facet of the H2020 work programs and underlined the EU leadership role in tackling global challenges associated with the green transition. Cooperation with third countries was important to broaden research perspectives and explore new approaches and solutions to green transition challenges in the smart and sustainable cities field. Moreover, the investments in international cooperation exposed partners to the demands of international markets and provided first market entry points to them. This aspect of collaboration is reflected in the project participation of partners from third countries.

What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

With regards to EU added value, the work programs have created highly ambitious EU flagship initiatives which have demonstrated how overarching policy objectives can be operationalised. The effectiveness of these interventions, and thus EU added value, can be further leveraged by improving the alignment with national strategies and activities in terms of finding synergies, complementarities, or multiplier effects at the national, regional or city levels in order to draw in additional stakeholders and tap into private and public sector funding streams. However, a discrepancy in EU added value between the EU 15 and EU 13 member states (see Annex, Quant results) is eminent, which is rooted in historically grown structural differences of the national R&I systems between both groups. Although the participation of the EU13 Member States is high (they were involved in 92% of the projects), the EC contribution is still very low at 5.7% of the total contribution (in comparison, EU15 countries receive 85% of the total contribution with a funding of 461 million of Euros). This innovation gap limits the potential to achieve EU-wide policy priorities associated with a green transition in the smart and sustainable cities field.

4.5. Annexes

4.5.1. Key metadata of the case study no. 4 ‘Sustainable and Smart Cities’

Table 45. Key metadata of case study no. 4 ‘Sustainable and Smart Cites’.

Case no. 4	**Sustainable and Smart Cities**
Evaluation Question addressed*	EQ 4.2.; 4.3; 4.4.; 4.5.; 5.1.
Area	Energy
Programme parts	WP 2014/2015 (Energy) WP 2014/2015 (Climate)

Case no. 4	Sustainable and Smart Cities
	WP 2016/2017 (Part17 Cross-Cutting Activities) WP 2018/2020 (Part 10 - Secure, clean and efficient energy) WP 2018/2020 (Part 20 – Cross-Cutting Activities) WP 2018/2020 (Climate action, environment, resource efficiency and raw materials)
Scope	12 Horizon 2020 calls & 5 JPI Urban Europe Calls (ERA NETS) Time horizon covered: 2014 – 2020. Number and type of instruments analyzed: 5 RIAs, 2 CSAs, 5IAs and 5 ERA NETS. Number of projects analysed: 41
Key data sources	H2020 Work Programs & relevant call text JPI UE call texts (ERA NETS) Project data from CORDIS & CORDA 5 interviews (2 Experts, 1 Policy Officer, 1 Partnership Representative, 1 Project Beneficiary) Strategic Policy Documents (JPI UE SRI 1 & 2; Set Plan Implementation Plan)
Links with partnerships	JPI Urban Europe and related ERA-NET Cofund Calls: Smart Cities, and Communities (ENSCC) (2014), Smart Urban Futures Call (ENSUF) (2015), Urban Accessibility and Connectivity (ENUAC) (2019), ERA-NET Cofund Urban Transformation Capacities (ENUTC) (2021)
Relevant policies	United Nations Human Settlement Program New Urban Agenda Sustainable Development Goal 11 Global Covenant of Mayors European Urban Agenda Juncker Plan European SET Plan European Green Deal EU Urban Initiative EU Covenant of Mayors

Table 46. Project information.

Project Acronym	Project Call ID	Action Type	EC Net Contribution	Project Start	Project End
ATELIER	H2020-LC-SC3-2019-ES-SCC	IA	19.607.836	01/11/2019	31/10/2024
CITYKEYS	H2020-SCC-2014	CSA	962.846	01/02/2015	31/01/2017
CityxChange	H2020-LC-SC3-2018-ES-SCC	IA	19.999.996	01/11/2018	31/10/2023
CLAiR-CITY	H2020-SC5-2015-two-stage	RIA	6.692.548	01/05/2016	31/07/2020
CLEARING HOUSE	H2020-SC5-2018-2	RIA	4.986.464	01/09/2019	31/08/2023
CLEVER Cities	H2020-SCC-NBS-2stage-2017	IA	14.214.661	01/06/2018	31/05/2023
CONEXUS	H2020-SC5-2019-2	RIA	4.999.940	01/09/2020	31/08/2024
CONNECTING Nature	H2020-SCC-NBS-2stage-2016	IA	11.394.282	01/06/2017	31/05/2022
EdiCitNet	H2020-SCC-NBS-2stage-2017	IA	11.254.913	01/09/2018	31/08/2023
ESPRESSO	H2020-SCC-2015	CSA	1.059.913	01/01/2016	31/12/2017

EuPOLIS	H2020-SC5-2019-2	IA	9.995.190	01/09/2020	31/08/2024
GO GREEN ROUTES	H2020-SC5-2019-2	IA	10.485.805	01/09/2020	31/08/2024
GROW GREEN	H2020-SCC-NBS-2stage-2016	IA	11.224.058	01/06/2017	31/05/2022
GrowSmarter	H2020-SCC-2014	IA	24.820.974	01/01/2015	31/12/2019
ICARUS	H2020-SC5-2015-two-stage	RIA	6.472.015	01/05/2016	31/10/2020
IN-HABIT	H2020-SC5-2019-2	IA	10.621.931	01/09/2020	31/08/2025
INTERLACE	H2020-SC5-2019-2	RIA	5.476.165	01/09/2020	31/08/2024
IRIS	H2020-SCC-2017	IA	17.996.569	01/10/2017	31/03/2023
iSCAPE	H2020-SC5-2015-two-stage	RIA	5.850.829	01/09/2016	30/11/2019
MAKING-CITY	H2020-LC-SC3-2018-ES-SCC	IA	18.089.583	01/12/2018	30/11/2023
MAtchUP	H2020-SCC-2017	IA	17.418.339	01/10/2017	30/09/2022
MULTISOURCE	H2020-SC5-2020-2	RIA	4.999.631	01/06/2021	31/05/2025
mySMARTLife	H2020-SCC-2016	IA	18.656.102	01/12/2016	30/11/2021
Nature4Cities	H2020-SCC-NBS-1stage-2016	RIA	7.499.981	01/11/2016	30/04/2021
NATURVATION	H2020-SCC-NBS-1stage-2016	RIA	7.797.878	01/11/2016	31/05/2021
NetZeroCities	H2020-LC-GD-2020-2	RIA	52.996.605	01/10/2021	30/09/2025
NICE	H2020-SC5-2020-2	RIA	4.996.342	01/06/2021	31/05/2025
POCITYF	H2020-LC-SC3-2019-ES-SCC	IA	19.998.275	01/10/2019	30/09/2024
proGIreg	H2020-SCC-NBS-2stage-2017	IA	10.432.512	01/06/2018	31/05/2023
REGREEN	H2020-SC5-2018-2	RIA	4.996.172	01/09/2019	31/08/2023
REMOURBAN	H2020-SCC-2014	IA	21.541.949	01/01/2015	30/06/2020
RESPONSE	H2020-LC-SC3-2020-EC-ES-SCC	IA	19.820.169	01/10/2020	30/09/2025
Ruggedised	H2020-SCC-2016	IA	17.692.858	01/11/2016	31/10/2021
SPARCs	H2020-LC-SC3-2019-ES-SCC	IA	19.701.216	01/10/2019	30/09/2024
STARDUST	H2020-SCC-2017	IA	17.939.999	01/10/2017	30/09/2022
Triangulum	H2020-SCC-2014	IA	25.420.602	01/02/2015	31/01/2020
UNALAB	H2020-SCC-NBS-2stage-2016	IA	12.768.932	01/06/2017	30/11/2022
URBAN GreenUP	H2020-SCC-NBS-2stage-2016	IA	13.970.642	01/06/2017	31/05/2022
URBiNAT	H2020-SCC-NBS-2stage-2017	IA	13.019.300	01/06/2018	30/11/2023
VARCITIES	H2020-SC5-2019-2	IA	10.115.469	01/09/2020	28/02/2025

4.5.2. Tables of Horizon 2020 calls analysed

Table 47. H2020 calls analysed.

WP 2014/2015 (Energy)	1. SCC 1 – 2014/2015: Smart Cities and Communities solutions integrating energy, transport, ICT sectors through lighthouse (large scale demonstration - first of the kind) 2. SCC 2 – 2014 92: Developing a framework for common, transparent data collection and performance measurement to allow comparability and replication between solutions and best-practice identification

	3. SCC 3 – 2015 93: Development of system standards for smart cities and communities solutions
WP 2014/2015 (Climate)	4. SC5-4-2015: Improving the air quality and reducing the carbon footprint of European cities
WP 2016/2017 (Part17 Cross-Cutting Activities)	5. SCC1-2016-2017: Smart Cities and Communities lighthouse projects 6. SCC-02-2016-2017: Demonstrating innovative nature-based solutions in cities 7. SCC-03-2016: New governance, business, financing models and economic impact assessment tools for sustainable cities with nature-based solutions (urban re-naturing)
WP 2018/2020 (Part 10 - Secure, clean and efficient energy)	8. LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities
WP 2018/2020 (Part 20 – Cross-Cutting Activities)	9. LC-GD-1-2-2020: Towards Climate-Neutral and Socially Innovative Cities
WP 2018/2020 (Climate action, environment, resource efficiency and raw materials)	10. SC5-13-2018-2019: Strengthening international cooperation on sustainable urbanisation: nature-based solutions for restoration and rehabilitation of urban ecosystems 11. SC5-14-2019: Visionary and integrated solutions to improve well-being and health in cities 12. SC5-27-2020: Strengthening international collaboration: enhanced natural treatment solutions for water security and ecological quality in cities

4.5.3. Overview of related ERA-NETs

The following ERA-NET CoFunds have been funded under Horizon 2020 in relation to Sustainable and Smart Cities under the umbrella of JPI Urban Europe:

Smart Cities and Communities (ENSCC, 01/2016-05/2020) call focused on the topics 1) Smart Integrated Urban Energy and Transport Systems, 2) Smart Tools and Services for Integrated Urban Energy and Transport Systems, 3) Smart Data, Big Data, and 4) Smart Governance and Smart Citizens. It funded 17 projects with a total budget of EUR 18,311,540.

Smart Urban Futures (ENSUF, 01/2017 – 03/2021) calls on cities and civil society in Europe to address urgent and long-term challenges by co-creating ideas and projects. It funded 15 projects with a total budget of EUR 15,162,788.

Urban Accessibility and Connectivity (ENUAC, 01/2021 – 05/2024) invited researchers, cities, municipalities, businesses, civil society and other stakeholders to build transnational consortia to create challenge-driven innovation and research projects that address the challenges of sustainable urban passenger mobility, freight, transport and connectivity as integral and essential parts of sustainable urban development. It currently funds 15 projects with a total budget of EUR 18,994,303.

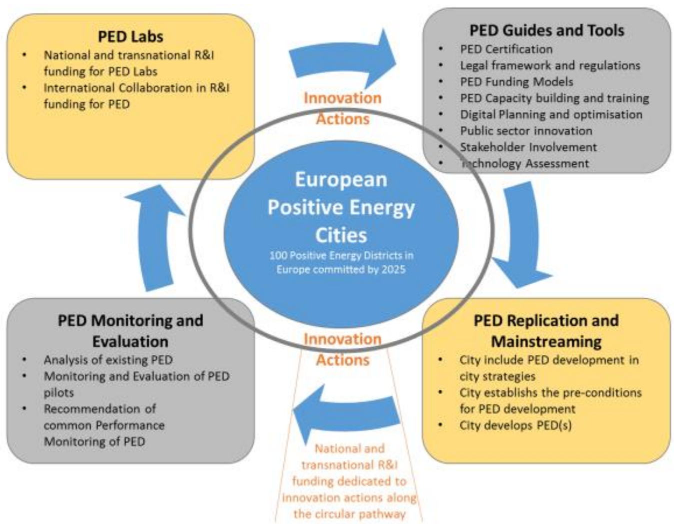
The Sustainable Urbanisation Global Initiative (SUGI)/Food-Water-Energy Nexus (01/2018 – 05/2022) was a call jointly established by the Belmont Forum and the Joint Programming Initiative Urban Europe. The cooperation was established in order to bring together the fragmented research and expertise across the globe to find innovative new solutions to the Food-Water-Energy Nexus challenge. It funded 15 projects with a total budget of EUR 22,276,683.

Table 48. ERA-NET CoFund in JPI Urban Europe.

JPI Urban Europe Call Name	Month & Year the call opened	Number of projects funded	Total budget
ERA-NET Cofund Smart Cities and Communities (ENSCC)	Dec. 2014	17	18,4 M€
Sustainable Urbanisation Global Initiative (SUGI)/Food-Water-Energy Nexus	Dec. 2016	15	22.3 M€
Smart Urban Futures (ENSUF)	Jan. 2017	15	15,2 M€
ERA-NET Cofund Urban Accessibility and Connectivity (ENUAC)	Dec. 2019	15	22,3 M€

A complete overview of funding per call of JPI Urban Europe can be found here: https://jpi-urbaneurope.eu/explore/

4.5.4. International and European strategies related to sustainable and smart cities



At the international level, the United Nations Human Settlement Programme (UN-HABITAT) (housing and sustainable urban development) and the New Urban Agenda highlight the policy requirements on a global scale for an "integrated sustainable development) and the 2030 Agenda for Sustainable Development Goals (SDG 11) stress the overarching target to make cities inclusive, resilient and sustainable. The Global Covenant of Mayors for Climate & Energy, with a strong European presence, envisions a world where committed mayors and local governments – in alliance with partners – accelerate ambitious, measurable climate and energy initiatives that lead to a low-emission and climate-resilient future[112] by focussing on support for local governments, partnering with city networks and reducing emissions and fostering climate resilience.

At the European level, the European Urban Agenda (Pact of Amsterdam, May 2016) set up a new multi-level working method promoting cooperation between Member States, cities, the European Commission and other stakeholders focusing on capacity building for strategy development and support for priority themes for EU cities including, energy transition, digital transition, climate adaptation, urban mobility and sustainable use of land and nature-based solutions[113]. Within the Juncker Plan (reflected in the thematic priorities of JPI Urban Europe), the ITRE committee (Industry, Research and Energy) of the European Parliament voted for the ring-fencing of EUR 5 billion (among

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[112] See: https://www.globalcovenantofmayors.org/what-is-our-mission/

[113] See: https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development_en

the EUR 21 billion of EU guarantees) in the European Fund for Strategic Investment (EFSI) to fund energy efficiency projects that shall "support projects promoted by cities and local governments" in priority[114].

At a strategic energy technology policy level, the European SET-Plan (Action n3.2) from 2016 sets the target for Europe to become a "global role model/market leader in technology integration for and deployment of net–zero- energy/emission districts (ZEED) with the aim by 2025 to have at least 100 successful examples synergistically-connected to the energy system in Europe and a strong export of related technologies"[115]. Therefore, Working Group 3.2 developed an integrative approach to Positive Energy Districts (PED) in 2018, including technological, spatial, regulatory, financial, legal, environmental, social and economic perspectives, which was integrative considered in the Strategic Research and Innovation Actions of JPI Urban Europe and related ERA-NET calls[116].

As part of the Green Deal[117] (2019), the Climate Neutral and Smart City Mission is a cornerstone of a green European City Strategy, going beyond the targets of the SET-Plan. Furthermore, related to cities, the EC Green Deal stresses that 1) transport should become drastically less polluting, especially in cities, 2) the biodiversity strategy will also include proposals to green European cities and increase biodiversity in urban spaces, 3) the proposed European Urban Initiative[118] shall provide assistance to cities…to develop sustainable urban development strategies, and 4) that the EU Covenant of Mayors will continue to be a central force to provide assistance to cities and regions that want to commit to ambitious pledges on climate and energy policies. In 2020 also, the Sustainable and Smart Mobility Strategy added another layer to EU R&I policy making in the EU city policy context.

5. Case study 5: A single smart European electricity grid

5.1. Summary

This case study identifies and analyses relevant actions related to the single, smart European electricity grid in H2020 and respective partnerships (Supporting Joint Actions and ERA-NET Co-Fund). This case study focuses on activities to integrate digital technologies into the traditional power system, transforming it into a cyber-physical system, the smart grid. This technology will enable decarbonizing the electricity system, thus critically contributing to the EU´s climate change and security of supply policies. Therefore, smart grids play a cross-cutting role in the Energy Challenge lines. With a focus on trans-national and European integration of power grids, the support measures cover the full spectrum of technology readiness levels, from technology development to large-scale demonstration as well as enabling flexibility and stability both in wholesale and retail electricity markets with a high share of renewables.

The present case study shows that the work programmes have successfully established an active innovation community with a wide range of projects directed at next generation technologies and tools for grid automation, the integration of storage, energy system integration and increasing the share of renewables in the electricity system. On the one hand, the democratisation of the electricity system is furthered by developing local energy networks and implementing flexibility and peer-to-peer retail markets, and on the other hand, the European-wide cross-border system integration in transmission grids and regional cross-border cooperation is supported. Alongside knowledge and technology development, a strong focus is laid on innovation and roll-out – prototyping, testing, demonstrating, piloting, to large-scale product validation and market replication.

[114] See: https://energy-cities.eu/juncker-plan-european-parliament-decides-to-support-local-energy-efficiency-projects/
[115] See: https://setis.ec.europa.eu/document/download/981ec576-7bc2-48d2-af26-1f622f7c701a_en?filename=action3_2_scc_declaration_of_intent.pdf
[116] See: https://jpi-urbaneurope.eu/wp-content/uploads/2021/10/setplan_smartcities_implementationplan-2.pdf
[117] See: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52019DC0640&from=EN
[118] See: https://futurium.ec.europa.eu/en/urban-agenda

Table 49. Key metadata of case study no. 5 'A single, smart European electricity grid'.

Case Study No. 5	**A single, smart European electricity grid**
Evaluation Question addressed*	EQ 4.1.; 4.2.; 4.3.; 4.4.; 5.1.
Area	SC 3
Programme parts	WP 2014/2015 (Part 10 – Secure, clean and efficient energy) WP 2016/2017 (Part 10 – Secure, clean and efficient energy) WP 2018/2020 (Part 10 – Secure, clean and efficient energy) WP 2018/2020 (Part 20 – Cross-cutting activities)
Scope	Time horizon covered: 2014 – 2020 Number and type of instruments analysed: 33 IA, 35 RIA, 3 CSA Number of projects analysed: 71
Key data sources	Strategic Policy Documents H2020 Work Programs & relevant call texts CORDIS data Project websites Interviews with beneficiaries and stakeholders
Links with partnerships	Supporting Joint Actions on the demonstration and validation of innovative energy solutions ERA-NET Co-Fund Enhanced cooperation in Smart Local and Regional Energy Networks of the European Energy System ERA-NET Co-Fund Enhanced cooperation in Digitalisation of Energy Systems and Networks
Relevant policies	UNFCCC / SDG7 / Mission Innovation Europe 2020 strategy SET-Plan Clean Energy for all Europeans European Green Deal REPowerEU

5.2. Introduction and overview

5.2.1. Objectives

The present case study on the single, smart European electricity grid identifies and analyses the relevant actions in Horizon 2020 (H2020) and respective partnerships. The main objectives of this study are i) to assess how effective the implementation of H2020 was in establishing the European smart grid and ii) to show how the results and outcomes of the actions contributed to the overarching H2020 goals, hereby laying a special focus on the contributions to the newly raised Green Transition ambitions of the European Commission (EC). Against this background, indications are sought for aspects that could be further scaled up or improved in the smart grid area under the current Framework Programme, Horizon Europe.

5.2.2. Methodology and case study structure

The methodological approach for this case study comprises three levels of analysis, i) the objective level, based on strategic documents setting the framework for the topic, ii) the input level, comprising the H2020 Work Programmes (WP) and the calls relevant for this case study, and iii) the activities level, referring to the projects funded under H2020 (**Error! Reference source not found.**).

Figure 228 Analytical steps of the case study.

Desk research was conducted on programme documents of H2020 (work programmes, relevant call texts), strategic documents related to smart grids and other sources communicating H2020 results, especially the knowledge community gathered under the BRIDGE initiative. Based on a sample of relevant calls in the work programme (identified by a full-text search with the umbrella term "grid" and manual narrowing down to calls where the modernisation of the electricity grid at the European scale is at the core), project data as available from Cordis/Corda were analysed and complemented by additional sources like project websites.

Table 50. H2020 WPs and calls for the sampled projects in the case study Smart Grids.

WP 2014/2015 (Part 10 – Secure, clean and efficient energy)	LCE 6 – 2015: Transmission grid and wholesale market LCE 7 – 2014: Distribution grid and retail market
WP 2016/2017 (Part 10 – Secure, clean and efficient energy)	LCE-01-2016-2017: Next-generation innovative technologies enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network LCE-02-2016: Demonstration of smart grid, storage and system integration technologies with increasing share of renewables: distribution system LCE-03-2016: Support to R&I strategy for smart grid and storage LCE-04-2017: Demonstration of system integration with smart transmission grid and storage technologies with increasing share of renewables LCE-05-2017: Tools and technologies for coordination and integration of the European energy system
WP 2018/2020 (Part 10 – Secure, clean and efficient energy)	LC-SC3-ES-1-2019: Flexibility and retail market options for the distribution grid LC-SC3-ES-2-2019: Solutions for increased regional cross-border cooperation in the transmission grid LC-SC3-ES-5-2018-2020: TSO – DSO – Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation LC-SC3-ES-6-2019: Research on advanced tools and technological development LC-SC3-ES-7-2018: Pan-European Forum for R&I on Smart Grids, Flexibility and Local Energy Networks
Supporting Joint Actions and ERA-NET Co-fund	LCE-18-2014 - Supporting Joint Actions on demonstration and validation of innovative energy solutions LCE-37-2017: ERA-NET Co-Fund Enhanced cooperation in Smart Local and Regional Energy Networks of the European Energy System LC-SC3-ES-9-2019: ERA-NET Co-Fund Enhanced cooperation in Digitalisation of Energy Systems and Networks

In addition to the project data analysis, we performed 6 interviews with core stakeholders that were able to cover a broad range of domains in smart grids. These interviewees comprised the roles of scientists, thematic experts, project beneficiaries and stakeholders from the power sector. The interviews followed a semi-structured, exploratory approach that was harmonized for all case studies and adapted to the perspective of the specific smart grid stakeholder group. For synthesizing the analysis, we triangulated and analysed the findings in relation to the evaluation questions.

5.3. Synthesis of evidence / Findings

5.3.1. Digitalization of the power grid and energy system integration

The power grid was originally designed to deliver electricity from large power plants via a high-voltage network to local electric distribution systems that supply individual consumers. It is sometimes referred to as a huge and complex machine that serves hundreds of millions of users. The current **digitalisation of this electricity network** towards a system with a two-way flow of both electricity and information between providers and users is based on a new concept of electricity network – the smart grid[119]. This new development changed the trend in decades of grid evolution: Smart grids can **integrate** a diverse set of electricity resources, including large power plants as well as **distributed renewable resources, electric energy storage, demand response and electric vehicles**, resulting in lower costs, higher efficiency, grid reliability and stability, and ultimately lower environmental impacts.

Smart grids are seen as a core **enabler of decarbonizing the electricity system** and thus contribute to climate change and the security of supply policies. They play a key role in facilitating this incremental system transformation of electricity supply, consumption, and grid operation. Facing the liberalization of the electricity sector and the corresponding regulatory frameworks, smart grid technologies promise to meet the challenges related to distributed and intermittent generation, responsive demand as well as storage, and the integration of large-scale renewable energy sources. Thus, the grid must be upgraded with respect to technology innovation, grid services and user participation[120].

5.3.2. Strategic policy priorities related to the single, smart European electricity grid

Among the United Nations´ **Sustainable Development Goals (SDG)**, renewable energy generation, energy efficiency and ensuring access to energy for all are core objectives (**Affordable and Clean Energy, SDG7**). In this context, investment into smart electricity grids is highlighted as an essential step in the energy transition[121]. **Mission Innovation (MI)[122]** was started at COP21 as a high-level global initiative of willing countries to catalyse investment in RTD to make clean energy affordable, attractive and accessible to all, supporting progress towards the Paris Agreement goals and pathways to net zero. Smart grids are the first so-called MI Innovation Challenge to accelerate the global development and demonstration of smart grid technologies to enable affordable, reliable, decentralised renewable electricity systems.

At the EU level, the decarbonization of the electricity system has become a strategic priority. One of the most important was the **Europe 2020 strategy[123]**, setting the 20/20/20 targets for the energy sector—to increase renewable energy consumption by 20%, to reduce energy consumption by 20% with respect to 2020 forecasts and to reduce greenhouse gas (GHG) emissions by 20% with respect to 1990 levels. By 2030, these targets would need to be further tightened to be on track to reach a GHG reduction of between 80-95% by 2050, consistent with the internationally agreed target to limit atmospheric warming to below 2°C (**2030 framework for climate and energy policies**)[124].

To achieve these mid- and long-term goals, the EU invoked its **Strategic Energy Technology Plan (SET-Plan)[125]** in 2008, where a broad range of technology challenges are being tackled, and the smart European electricity grid is one of the core technology focuses. The SET-Plan seeks to maximise synergies between EU and national public R&I support for clean energy and to strengthen the

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[119] For a brief overview of the main concepts, technologies and implementation status of smart grids see, for instance, Ardito et al. 2013 and Sospiro et al. 2021.

[120] Meeus, L., M. Saguan, J.-M. Glachant and R. Belmans (2010). Smart regulation for smart grids. Florence School of Regulation Working Paper RSCAS 2010/45. European University Institute, Robert Schuman Centre for Advanced Studies, Florence, Italy.

[121] United Nations (2021). Leveraging energy action for advancing the sustainable development goals. Policy briefs in support of the High-level Political Forum. https://sdgs.un.org/sites/default/files/2021-06/2021-SDG7%20POLICY%20BRIEFS.pdf

[122] http://mission-innovation.net/

[123] European Commission (2010). Energy 2020 A strategy for competitive, sustainable and secure energy. COM(2010) 639 final. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0639:FIN:En:PDF

[124] European Commission (2013). A 2030 framework for climate and energy policies. COM(2013) 169 final. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0169:FIN:en:PDF

[125] European Commission (2007). A European Strategic Energy Technology Plan (SET-PLAN) "Towards a low carbon future". COM(2007) 723 final. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0723&from=EN

partnership with the Member States. To support its implementation in the electricity sector, the **European Technology and Innovation Platform Smart Networks for Energy Transition (ETIP-SNET)**[126] was created. In addition, the EC also pursues its policy goals through bi-lateral international cooperation and contributing to international organizations, such as the Technology Collaboration Programmes (TCPs) of the International Energy Agency (IEA) and the Mission Innovation Initiative. In 2016, the EC proposed the **'Clean Energy for all Europeans' package** of measures which pursues three overarching goals: (i) energy efficiency first, (ii) Europe as a leader in renewables, and (iii) a fair deal to consumers. Smart grids as a technology infrastructure play a significant role in all policy measures implemented towards these goals.

The **European Green Deal** was launched by the von der Leyen Commission to give top priority to climate change and to make Europe climate neutral by 2050. It is one of the six top EC priorities for 2019-24. The EC estimates that to achieve the current EU´s 2030 climate and energy targets, investments of EUR 13bn into the European power grid are needed, a figure experts tend to consider as an underestimation[127]. Moreover, the reallocation of capital towards new technologies to decouple growth and GHG emissions should be the main strategy.

The recent energy crisis and global energy market disruption caused by Russia´s invasion of Ukraine has called on the EC to launch **RePowerEU**[128], a plan to "rapidly reduce dependence on Russian fossil fuels and fast forward the green transition." To secure energy supply, increase the share of renewables, digitalise the EU energy market and improve system efficiency, interconnected energy systems and better-integrated grids are seen as prerequisites. While immediate action is directed towards energy saving and diversifying gas supplies through the newly created EU Energy Platform, medium-term actions are planned for accelerating the rollout of renewables, and heat pumps and simplifying permitting processes for renewable production sites. All of this will directly challenge the capacity of the electricity grid and call for a reinforcement of digitalised electricity grid and for speeding-up of smart grid technologies.

5.3.3. Horizon 2020 programming related to the single, smart European electricity grid

Smart grids play a cross-cutting role in a wide range of Energy Challenge lines, e.g., increasing overall energy system efficiency, integrating storage in an increasingly distributed and dynamic electricity system or establishing energy islands. To narrow down the scope to a consistent and manageable scale, the study focuses on such activities where the modernisation of the electricity grid at the European scale is at the core, comprising relevant R&I and policy strategies, technology development and deployment in large-scale demonstrations at transmission and distribution levels as well as looking into wholesale and retail markets.

5.3.3.1. Horizon 2020 Work Programmes related to Smart Grids

In the first biannual work programme (2014-2015), smart grids activities cover the full spectrum of **demonstration and R&D** activities ranging from interoperable technologies, services, tools, system integration, network synchronisation, co-ordination schemes, business models, cost-benefit analyses to market architectures, rules and regulatory regimes for upgrading and reinforcing the pan-European power system. Solutions are sought for improving flexibility and available capacity of European electricity grids at high voltage levels (transmission) and also for increasing flexibility and the share of micro-generation and renewable generation at low voltage levels in local grids (distribution).

The Work Programme 2016-2017 refocused on **technologies and services for demand-response, smart grid, storage and energy system integration,** taking into account the stability and security in the context of an increasing share of variable renewable energy sources in the electricity grid. Technologies should clearly go beyond the state of the art and be ready to integrate the market in five to ten years' time, including the active consumer and storage technologies in the distribution network at medium and low voltage levels. Synergies between energy networks (e.g., power to heat, integration of grid users from transport) and technology validation for demand response forecast, profiling, segmentation, load forecasting, and innovative and user-friendly services are targeted.

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[126] European Commission (2006). European SmartGrids Technology Platform: vision and strategy for Europe's electricity networks of the future, Directorate-General for Research and Innovation. Publications Office.
[127] Claeys, G., S. Tagliapetra and G. Zachmann (2019). "How to make the European Green Deal work." Breugel Policy Contribution (JSTOR) 13. https://www.jstor.org/stable/pdf/resrep28626.pdf
[128] https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131

Support for the coordination of stakeholder views on R&I strategy is given using existing structures such as the Smart Grid Technology Platform, the EEGI and EERA, including an R&I roadmap for enhanced cross-border knowledge sharing and system optimisation. New technologies and business processes at local and regional levels are fostered and linked to the European energy system by providing additional EU-funds on top of national and regional RTD programmes (ERA-NET Co-Fund).

The Work Programme 2018-2020 addresses research, innovation and market uptake activities in the smart grid domain and aims to maximise synergies between EU and national public support for seamless integration into a European grid, also leveraging private funding. At the level of the distribution grid, flexibility and retail market options are to be demonstrated with grid services provided by storage, power to-X, demand response and variable distributed generation to enable decarbonisation. At the level of the transmission grid, increased regional cross-border flows, substantiated by new hardware and software solutions for communication and grid operation, will help to optimise the conditions for the wholesale market across the different market zones in Europe. Alongside demonstrators for coordination of transmission and distribution level operators, new tools and technologies are to be developed, first and foremost **new tools for markets and forecasting, grid planning and predictive management**, but also TSO-DSO coordination tools and new cost-effective decentralised storage technologies. A specific focus is laid on the establishment of a **pan-European forum for R&I** to integrate Member States lagging with respect to grid innovation activities. Above all, enhanced cooperation with Information and Communication Technology (ICT) research, demonstration and innovation programs are desired to develop future digital platforms which allow for a sustainable, secure and resilient energy system where data protection is guaranteed.

5.3.3.2. Summary of strategic policy priorities

RTD into smart grids has already gained increasing importance in FP6 and FP7, as they have been recognized as central to the low-carbon energy transition. However, according to evaluation studies, the impact on the energy sector was still considered low. The Europe 2020 strategy, setting the 20/20/20 targets for the energy sector, made it clear that the digitalisation of the electricity grid plays a critical role in integrating renewables, coupling different energy sectors, and enabling flexibility in markets. In this perspective, H2020 aimed at incrementally advancing technological development, implementation, and commercialisation of smart grids to support the energy transition. An important element in the EU´s smart grid activities is the coordination of European and national activities, according to the SET-Plan, which is also reflected in the activities of the European Technology and Innovation Platform Smart Networks for Energy Transition (ETIP-SNET) and the establishment of the partnership ERA-Net Smart Energy Systems.

As an enabling technology, smart grids are an integral part of all three biannual work programmes of Horizon 2020 in different programme parts (see **Error! Reference source not found.**). The calls initially focused on technological advances in the transmission as well as the distribution grid and corresponding markets by involving all stakeholders. In the second programming period, an additional focus was laid on the integration of renewables and European integration of the grid, while the third programming period embraced large-scale demonstrations, including market aspects like peer-to-peer contracting, flexibility, retailing and regional cross-border cooperation. As such, the evolutionary advancement of smart grids has already contributed to the green energy transition before the advent of the Green Deal. The pressure from the REPowerEU Plan is expected to reaffirm this ambition through energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy sources.

5.3.4. Project portfolio characteristics

The present case study focuses on a portfolio of 71 smart grid projects that were selected from the call topics listed in **Error! Reference source not found.** (see the full list of projects in ***Error! Reference source not found.****, page* ***Error! Bookmark not defined.***). 33 of the projects are Innovation Actions (IA), 35 are Research and Innovation Actions (RIA), and 3 projects are Coordination and Support Actions (CSA). Overall, the field is dominated by large IAs, the largest comprising 76 project participants and a total EC net contribution of EUR 22m.

5.3.4.1. Horizon 2020 project portfolio

This subsection gives a brief insight into the structure of project participation by organisation type, type of action, geographical coverage and the international collaboration network in the case study project sample.

Table 51. Type of organisations in the case study Smart Grids.

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1000)
		Nb	Share (%)	EUR (1000)	Share (%)	
HES	67	208	16%	96.095	18%	462,0
OTH	27	49	4%	19.191	4%	391,7
PRC	70	843	64%	305.647	58%	362,6
PUB	15	21	2%	4.167	1%	198,4
REC	67	193	15%	102.906	19%	533,2
Total (All types)	**71**	**1314**	**100%**	**528.006**	**100%**	**401,8**

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

Source: eCorda, own calculation

The sum of EC's net contribution is EUR 528m, of which 58% has been allocated to private companies, 19% to research organisations, 18% to higher education institutions, 4% to other organisations, and 1% to public bodies. The high share of funds granted to private companies is reflected in the project participation: 64% of the project participation comes from the private sector, while the higher education sector and the research organisations account only for 16% and 15% of the participation. This means that, on average, research organisations and higher education organisations on average receive the highest funding (EUR 533m and EUR 462m, respectively). Other organisations (consultants, associations) and public bodies, on the other hand, play a minor role in the smart grid-related calls, with 4% and only 1% of the participation. This result reflects the strong technological focus of the H2020 activities in smart grid development and the high relevance for industry organisations and the electricity sector stakeholders.

Table 52. Type of actions/instruments (grouped) in the case study Smart Grids.

Group of Action/instrument	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)
		Nb	Share (%)	EUR (1,000)	Share (%)	
IA	33	837	63,7%	354.069,2	67,1%	423,0
RIA	35	428	32,6%	165.051,7	31,3%	385,6
CSA	3	49	3,7%	8.884,6	1,7%	181,3
SME	0	0	0,0%	0,0	0,0%	N/A
Other	0	0	0,0%	0,0	0,0%	N/A
All types	**71**	**1314**	**100,0%**	**528.005,6**	**100,0%**	**401,8**

Source: eCorda, own calculation

With respect to the type of projects, with 67% of the funds allocated to Innovation Actions (IA), the smart grid case study portfolio is strongly dominated by innovation- and commercialisation-oriented research. Correspondingly, Research and Innovation Actions (RIA) play a smaller role, receiving only 31% of the EC funds. On the other hand, with only 3 projects (a share of 1.7% of the funding), Coordination and Support Actions (CSA) are represented only to a very small extent. We find only one CSA in each of the programming periods of H2020 related to smart grids. Compared with the total Green Transition project portfolio, where IAs account for 47% and the share of CSA comprises 7,4% of allocated funding, the smart grid project portfolio is strongly implementation-oriented. SME actions were excluded from the analysis.

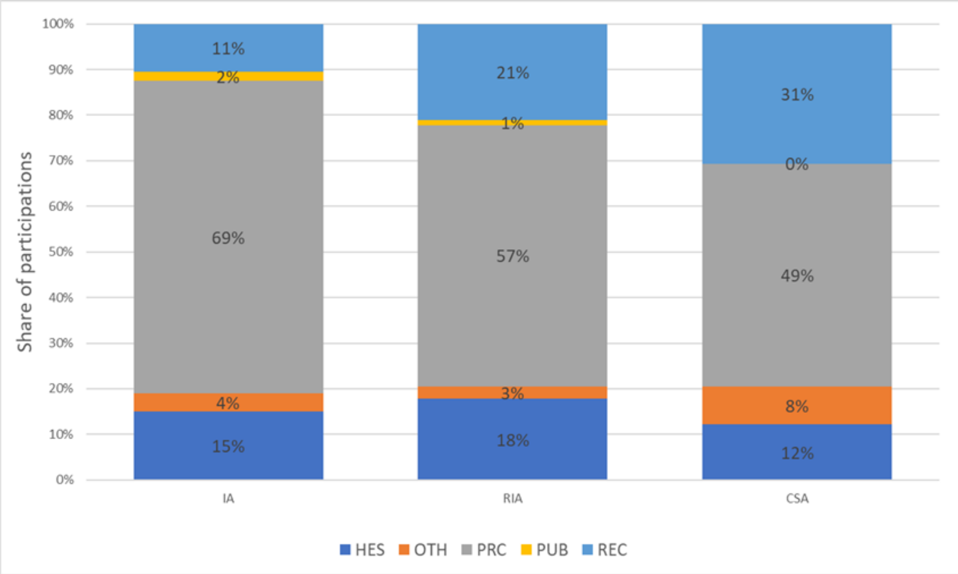

Figure 244. Share (%) of participations by type of action/instruments and organisations in the case study Smart Grids.
Source: eCorda, own calculation.

Figure 244 shows that the participation of private organisations is dominant in smart grid case projects. In Innovation Actions (IA) – with a funding rate of 70% (100% for non-profit entities) –private organisations represent 69% of the participation. Higher education organisations account for 15% of the participation, while 11% of participation is from public research organisations. This distribution also reflects the fact that the scope of IAs includes R&D only to a limited extent but focuses on prototyping, testing, demonstrating, and piloting, large-scale product validation and market replication. On the other hand, Research and Innovation Actions (RIA) aim at establishing new knowledge and/or exploring the feasibility of new or improved technologies or solutions. While private organisations still account for 57% of the participation, research organisations (21%) and higher education organisations (18%) play a much stronger role. Coordination and Support Actions (CSA) cover accompanying measures such as awareness-raising, networking, communication, dissemination and mutual learning exercises, coordination or support services and standardisation, but also policy dialogues. While private organisations still account for 49% of the participation, research institutions (31%) are much stronger than the other action types. It is worth noting that CSAs, Other organisations (associations in this case) are significantly more often involved (8%) than in IAs and RIAs but that no public bodies participate.

Table 53. Groups of countries (of supported organisations) in the case study Smart Grids.

Group of country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Number of countries
H2020-EU27	71	1 160	88,3%	464 423	88,0%	400,4	27
EU-14	*71*	*917*	*69,8%*	*393 035*	*74,4%*	*428,6*	*14*
EU-13	*48*	*243*	*18,5%*	*71 388*	*13,5%*	*293,8*	*13*
H2020-associated (exclude UK)	33	82	6,2%	34 619	6,6%	422,2	10
United Kingdom	34	70	5,3%	28 963	5,5%	413,8	1
Third Countries	1	2	0,2%	0	0,0%	0,0	1
All-countries	**71**	**1 314**	**100,0%**	**528 006**	**100,0%**	**401,8**	**39**

Source: eCorda, own calculation

The geographical distribution of smart grid projects shows that 88% of the EC funds go to EU27 countries, while 5.5% go to the UK, and 6.6% of the EC contribution is devoted to H2020-associated states (10 countries, excluding the UK). Within the EU, the lion's share (74.4%) goes to the “old” EU-14 countries, while only 13.5% are directed to the EU-13 (CEE member states accessed 2004 and later). These figures support the assumption that the EU-13 countries might have some catching-up to do, according to the case study project sample.

Table 54. Top countries (of supported organisations) in the case study Smart Grids.

Top 15 country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Order
Germany	46	108	8,2%	51 581	10%	477,6	1
Spain	45	168	12,8%	69 026	13%	410,9	2
Belgium	37	79	6,0%	33 045	6%	418,3	3
Italy	37	141	10,7%	44 869	8%	318,2	4
United Kingdom	34	70	5,3%	28 963	5%	413,8	5
France	30	69	5,3%	36 908	7%	534,9	6
Greece	29	81	6,2%	36 934	7%	456,0	7
Portugal	24	71	5,4%	28 207	5%	397,3	8
Austria	21	31	2,4%	14 853	3%	479,1	9
Netherlands	21	42	3,2%	15 960	3%	380,0	10
Denmark	17	33	2,5%	15 177	3%	459,9	11
Slovenia	17	49	3,7%	20 828	4%	425,1	12
Sweden	16	42	3,2%	21 106	4%	502,5	13
Cyprus	15	26	2,0%	9 224	2%	354,8	14
Romania	15	30	2,3%	8 568	2%	285,6	15

Source: eCorda, own calculation.

A ranking of countries by the number of smart grid projects reveals that Germany participates in most of the projects (46) but that Spain and Italy lead in the number of project participations (168 and 141, respectively). This puts Spain in the lead regarding the total allocation of EU funds (13%) over Germany (10%). A notable observation is the EC contribution per participant, which is highest in France and Sweden, with more than EUR 1m on average in smart grid projects.

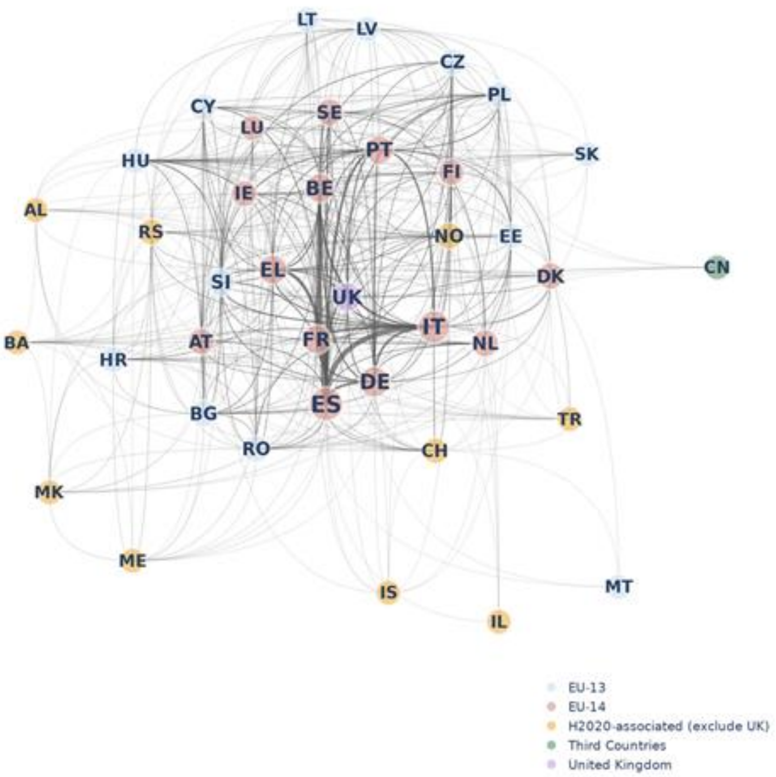

Figure 229 Network of participating countries in the case study Smart Grids.

Source: eCorda, own calculation.

The network of H2020 smart grid project collaborations (Figure 245) exhibits joint project participation of organisations from the participating countries. Hereby, proximity and link thickness reflect the number of mutual collaborations instantiated by the H2020 projects of this case study. The network shows a strong collaboration core represented by EU-14 countries, with the strongest links between Spain, France, Italy, Germany, Greece, and Belgium, in which also the UK is still centrally embedded. This can be interpreted as the core group of countries with respect to knowledge exchange and smart grid implementation activities. The EU-13 countries from CEE, on the other hand, are found in the area surrounding the network core, indicating links to specific core partner countries. H2020-associated countries are positioned in the periphery with less frequent collaboration links, notably at a distance comparable with the only Third Country in the network, China.

5.3.4.2. European Partnerships related to Smart Grids

In addition to the Horizon 2020 project portfolio, the European Union supports smart grid-related partnerships in the frameworks of **Supporting Joint Actions** and **ERA-NET CoFund**, a multilateral joint programming structure which is also coordinated with the European SET-Plan Action 4 initiative ('Increase the resilience and security of the energy system').

The overall goal of these initiatives is to support a comprehensive knowledge exchange between regional and European smart grid initiatives by promoting and funding joint projects and accompanying activities that build on the knowledge base, R&D initiatives, and research and demonstration facilities that already exist at regional, national, and European levels. Under this umbrella, annual calls are issued, and 82 projects have been funded (including the 2020 call), with 34 funding partners from 26 participating countries (including associated countries)[129]. The list of projects implemented to date under these partnerships is given in Annex 6.3.

The following actions are covered in this case study:

- **ERANet SmartGridPlus[130]:** Support deep knowledge sharing between regional and European Smart Grids initiatives (LCE-18-2014, GA No. 646039, 2015-2020), Total cost € 30 853 961,72; EU contribution € 9 149 908,26.
  The objective is to overcome the fragmentation of knowledge and accelerate knowledge exchange with the goal of developing European-wide interoperable solutions according to a common reference architecture. Critical masses shall be reached in the development of a European market for smart grid technology providers and smart grid service providers. The initiative does not intend to find the final specifications for smart grids but to organise the learning down to regional Smart Grids stakeholders towards implementation.

- **EN SGplusRegSys[131]:** A European joint programming initiative to develop integrated, regional, smart energy systems enabling regions and local communities to realize their high sustainable energy ambitions (LCE-37-2017, GA No. 775970, 2018-2023); Total cost € 36 406 227,79; EU contribution € 12 014 055,18.
  Building on structures already established by ERA-Net Smart Grids Plus, the action aims at solutions that allow for a high proportion of renewables up to and beyond 100% in the local or regional supply and for accelerating the deployment of the latest resource-efficient and decarbonising energy system solutions. It comes up with a new approach, developing integrated, regional energy systems, including the full spectrum of energy carriers and infrastructures, and piloting new formats of collaboration with regional and local stakeholders as well as supply and demand side-oriented technology policy.

- **EnerDigit[132]:** ERA-Net Digitalisation of Energy Systems and Networks (LC-SC3-ES-9-2019, GA No. 883973, 2020-2025), Total cost € 27 100 523,93; EU contribution € 8 907 285,42. Exploiting the coordination structures already established in the previous actions, a new 'Focus Initiative' is being established. It aims to enhance the transnational collaboration in the digital transformation of energy systems and networks. It helps unleash the potential of digitalisation for the energy transition towards a de-carbonised, secure and resilient European energy system. It initiates a Transnational Validation Ecosystem with living labs, start-ups and innovative companies to test their solutions in different frameworks. It also promotes the development of interoperable solutions, enabling wider impact and use of applications, systems and services, by piloting a European Collaboration Platform for Interoperability Testing, for developers, manufacturers and suppliers of components and solutions for smart energy systems.

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[129] https://www.eranet-smartenergysystems.eu/
[130] https://cordis.europa.eu/project/id/646039
[131] https://cordis.europa.eu/project/id/775970
[132] https://cordis.europa.eu/project/id/883973

In order to foster transnational learning and maximize impact, a Knowledge Community has been established as a core instrument for fostering exchange among all action stakeholders and external experts. The virtual knowledge-sharing platform *expera* and thematic working groups are complemented with communication means like policy briefs and spotlight documents that reflect the perspective of the Knowledge Community on the topics of System Architecture and Implementation Modelling, Storage and Cross Energy Carrier Synergies, Regional Matters, Regulatory and Market Development, as well as Consumer and Citizen Involvement. Close links are being upheld to other initiatives such as the ETIP SNET support project (Intensys4EU) or the Horizon 2020 Bridge initiative to enable a swift and coordinated input of the ERA-Net SES projects to the European SET-Plan Initiatives as well as the Grid-Innovation-Online platform.

5.4. Synthesis of findings

5.4.1. Results of the Horizon 2020 funding activities: pathways to impact

Our analysis of the H2020 Work Programmes and projects on smart grids revealed that distinct pathways to impact could be identified that link the activities carried out under the work programme with outcomes. This section provides an overview of the outcomes of the smart grids-related activities according to the five impact pathways of H2020 that have been used in this evaluation study.

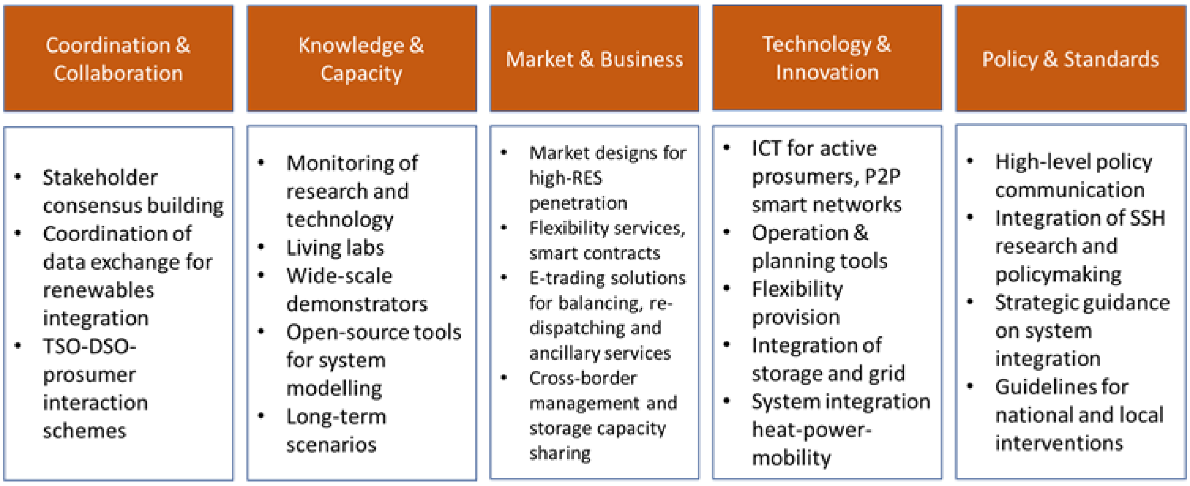

Figure 230 Expected outcomes across all analysed calls.

5.4.1.1. Coordination & Collaboration

The coordination and collaboration pathway aims at building consensus and acceptance among the stakeholders at international, European, national as well as local levels and alongside the energy value chain (e.g., ETIP-SNET or the BRIDGE process). Interaction schemes between transmission system operators (TSO), distribution system operators (DSO) and prosumers are implemented to improve data exchange and knowledge sharing about energy system optimization and establish a continuous process of interaction among all the stakeholders.

5.4.1.2. Knowledge & Capacity Building

The knowledge and capacity building pathway represents a key strategic area of H2020 and relates to scanning and monitoring Smart Grid research and technology development as well as training. Transnational initiatives and Living Labs – user-centred, open-innovation ecosystems often operating in a territorial context integrating concurrent research and innovation processes – facilitate the development and testing of prototypes, bringing innovative solutions from TRL4 (proof of concept) to TRL7. Wide-scale demonstrators provide inter-regional learning potentials for the European integration of smart grids. Hereby, open-source tools are preferred over proprietary solutions to promote the system modelling expertise on integrated multi-energy systems as democratically as possible. Public authorities especially benefit from the development of policy scenarios and transition roadmaps that outline the path to the European long-term 2050 targets.

5.4.1.3. Market & Business

The market & business pathway embraces the development of market architectures that allow for the highest-level penetration with intermittent renewable sources. Next-generation operating models and services will take a market-driven approach that democratizes the power sector through flexibility management tools and smart contracts to support local flexibility markets at the distribution grid level, especially energy cooperatives. E-trading solutions are being developed for electricity balancing and re-dispatching in Europe, as well as the provision of ancillary services is supported by demand-side management and distributed generation. A further important aspect of the market development pathway is the improvement of cross-border management of variable renewable energies and the deployment of large storage units enabling a transnational wholesale market.

5.4.1.4. Technology & Innovation

The technology and innovation pathway represents the backbone of Smart Grid activities in H2020, comprising the development of ICT tools for planning, management and operation of a dynamic, democratised power system with active consumers (prosumers). These solutions cover a wide range of electricity system elements, including secure ICT solutions, virtual power plants, architectures that facilitate high penetration with renewables, platforms for interactive consumer participation (peer-to-peer as well as transmission-distribution-customer relationship), and the provision of operational flexibility. New technologies are demonstrated, allowing the integration of storage and recovery solutions to the grid, both centralized and distributed, involving electric vehicles and the integration of power and heat networks as well as leveraging synergies with railways.

5.4.1.5. Policy & Standards

The policy and standards pathway emphasizes the provision of knowledge and experience for decision-makers at different policy levels through policy briefs as specific outputs of the projects. Research in social sciences and humanities (SSH) is being conducted in close collaboration with RTD and demonstration activities to inform EU energy policymaking. Strategic guidance is provided to policymakers raised by the European-wide system integration issues, and guidelines for developing and implementing national and local energy system interventions are prepared.

5.4.2. Findings related to the evaluation dimensions

Alongside the analysis of the Work Programmes and project activities, this evaluation study uses expert interviews to inquire about the set of evaluation dimensions. The questions specifically addressed in this case study were related to the effectiveness, and EU added value of the activities.

The interviews conducted so far cover EU project beneficiaries – both from research and industry – and transmission system operators as stakeholder groups, while information from distribution system operators provided additional information material on the topic. At this preliminary status of analysis, expert assessments are included from organisations that were or are participating in 25 of the 71 projects of the total case study sample.

Smart grid development activities are characterised by incremental innovation and the development of specific digitalisation solutions within a huge, complex technological system. The main activities are software and platform development for planning as well as operation, whereby advancement from low TRL to high TRL is considered to work well due to an integrated and collaborative approach in H2020 and partnership actions. Tools are developed both for research and industry, and there are success stories where the results are cumulatively adopted after the projects are completed and have a real impact in both sectors. Hereby, open-source solutions are preferred and have gained momentum to circumvent private standards and tools. Challenges to the implementation of new technologies are seen in lacking technical regulation, which is often not in place right in time. Also, the end-user perspective seems not to be sufficiently involved. Regarding sustainable development goals (especially carbon emission reduction), the full impact of smart grids will depend on speeding up their implementation. EU added value of H2020 and partnership activities is strongly endorsed, mainly regarding trans-border integration and their structuring effect on policies and funding at the national level.

5.4.2.1. *Specific findings related to Effectiveness*

EQ 4.1: What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results all together leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives, and by which timeframe?

The main characteristic of innovation in the electricity grid is the step-by-step establishment of a cyber-physical system. Hereby, it is envisaged that this is an alternative to classical grid expansion by introducing flexibility into the electricity system to use the existing grid infrastructure more efficiently and to enable the integration of intermittent renewable energy sources. Three aspects must be kept in mind, namely technical feasibility, legal admissibility and economic considerations. Project experiences show that technical solutions are very successfully provided at high readiness levels so that they can be implemented in the short term. According to an interviewee, a 2022 survey in the transmission sector revealed that methodologies and software tool development amount to 28% of the activities and 15% are related to hardware. Only 28% of projects are focused on users. Software development for research use, connecting universities and laboratories for joint development and testing is one part, and system simulation and system operation platforms for the private sector are the other activities. In this respect, one interviewee reported global impact through the successful use of various H2020 developments in the Americas.

In software development, the strategic approach always taken is to provide open-source solutions as a basis, and H2020 is seen to have significantly sped up the use of new open tools in real-world commercial applications. However, the challenge of technology lock-in remains. For instance, all auction networks in Europe are currently still connected through a single vendor, and new electricity providers (e.g., wind parks) must ultimately adapt to the same proprietary system.

However, there are barriers to the implementation of smart technologies because the technical infrastructure is not fully rolled out, and there are significant differences in preparedness across regions at the distribution level of the electricity system. Moreover, often the legal framework is not yet in place that would allow the application of smart technologies and, thus, new business models in a flexible electricity system. Summing up, it is highlighted that the implementation of new technologies still takes time after the completion of projects, and the follow-up of projects in terms of implementation is not always successful.

EQ 4.2: Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and longer term? Are there any factors that are more or less effective than others, and if so, what lessons can be drawn from this?

The programmes regarding technology development and implementation are very well structured – as seen by the interviewees – in a comprehensive approach involving all stakeholder groups and in a cumulative development strategy from lower to higher TRL levels. The technology platform allows for incremental enrichment with functionalities on the part of the users.

Despite this convincing process on the development part, regulation still plays a key role in the implementation of new digital solutions. Changes in regulation and market frameworks have to be accommodated to project results in a timely manner. Still, regulations often do not reward lead operators for replacing traditional infrastructure with smart solutions. Regulatory sandboxes may help in this respect, and interviewees consider that everyone is open to that. But the concept still needs to be developed to be fully functioning since it is difficult to cover all necessary aspects. For instance, a big challenge is to deal with data flows among the different stakeholders with respect to privacy and security issues.

Issues regarding the roll-out of digital technologies are also seen in the sectoral structure: While the transmission system level, with 30+ players in Europe, is already very well interoperable, and all exchange processes, for instance, cross-border trading, cross-border regulation, and cross border management are in place. In contrast, the distribution system level consists of 2000+ heterogeneous players and interoperability to harmonize all the data flows throughout Europe is not working sufficiently well. Following a unanimous opinion of interviewees, distribution system operators, in general, are still not well prepared for the implementation of the smart grid, and there are considerable differences across the sector. Thus, in most countries monitoring the grid is still impossible. It has been pointed out in an interview that also the Framework Programmes have not successfully addressed this issue. While the transmission grid has been very successfully upgraded in the first place, a later focus has been the end-user of electricity (turning the consumer into a prosumer). It is opined that the current funding focus is being shifted back to the transmission level while the distribution level is still neglected – reflecting the political power of incumbent stakeholders.

The missing legal framework seems to a large extent to be responsible for the lagging implementation of smart technologies at the intermediary (i.e., the distribution) level: For instance, virtual energy communities could provide a substantial contribution to local flexibility but cannot be established due to logistical and legal constraints. It was also noted that the grid infrastructure (existing copper lines) often provides sufficient capacity reserves for intermittent power, so there is not sufficient incentive to establish dynamic flexibility markets.

Efficiency considerations were brought forward with respect to the implementation of the actions. While H2020 implementation is considered efficient and well supported by the Commission, concerns have been raised with respect to the partnerships. ERA-Nets: although projects are leaner in scale, the management, reporting and documentation structures could be more formalized. Here, the actors would need more support from EC, maybe by using the same tools or sharing management experience.

A major issue regarding the wide roll-out of the smart grid and unleashing its potential with respect to the green transition is to include the customer and the citizen as a driving force. Still, the topic is, to a large extent, considered an industry-internal and technocratic issue. “It is hard to explain the benefits of flexibility to the guy in the street. Energy is considered a commodity, and that´s it”, as an interviewee puts it.

EQ 4.3: To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts? What further actions are needed to maximise the impact of the Framework Programme interventions in this area?

Dissemination, exploitation and communication measures are primarily to be seen in the open-source approach that is being followed throughout H2020 development activities. For instance, collaboration with the Linux Foundation for the governance of development processes allows for opening up of academic energy research and platforms to the software development community. Here, for developing solutions in a modular system, different services can be integrated in the platform. In this way, first commercial distribution management systems are based on open-source projects, and ongoing consultancy services help disseminating the knowledge developed.

An important role is seen in the communication processes implemented in H2020 projects, engaging the different grid stakeholders: Here, bilateral and multilateral interactions are found critical for the mutual establishment of trust. Special achievement in this respect is attributed to the knowledge exchange activities established in the ERA-NET Co-Fund Smart Energy Systems, which established a so-called Knowledge Community supported by internally and externally oriented communication measures and policy advice activities and integrating national and EU levels.

EQ 4.4: To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

Intrinsic support for SDGs, by enabling the integration of renewable energy sources into the power system and enabling the democratisation of the electricity system, has been present in the EU´s Framework Programme activities towards smart grids for a long time. Thus, it is welcomed that the EC pursues decarbonisation, decentralisation and democratisation in the power grid domain. In all these aspects, a smarter grid contributes to the decrease of carbon emissions, the emergence of new business models and market designs, and a decrease of network cost, thus the reduction of energy bills or improvement of network management. H2020 is considered to have brought a significant contribution to speeding up the provision of digital solutions. On the other hand, looking at to what extent smart grids have become a reality today, all in all, it's not that satisfactory.

Open-source development is something that will never be considered directly by the big companies, and the dominant tools are still provided by very few very large companies. H2020 is considered to have significantly shaken this structure and is considered to open up new chances and opportunities that the system really needs to speed up with respect to the SDGs. A lot of this contribution is seen to emerge already in the next one or two years.

Many regulation initiatives or regulated goals at the EU level, like the Green Deal and, more recently, the REPowerEU plan, are unchallenged drivers for the change. However, implementation still requires many national adaptations, including regional adaptations or adaptations to existing markets, with some time lag, and this seems to be the biggest challenge at present.

5.4.2.2. Specific findings related to EU-added value

EQ 5.1: What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed? Could the stakeholders have implemented their research and innovation in another way, including through other national or regional support?

According to the interviewees, one of the major achievements of H2020 is that it has brought industry in (as compared with the previous programme FP7 and with other countries like the United States). At the European level, developing a smart grid architecture and proposing enrichments in the form of new services for utilities and manufacturers help to bring the product to market.

In large EU member states, funding schemes and the amount of national funding is extremely broad and strong, so in these cases, the EU funds are not used in the first place. But there are still different impact dimensions of the EU-level activity on the overall European performance. One is the fact that the FPs bring the trans-border and the European perspectives to the national activities enlarging resource scope and pushing harmonization when it comes to drafting national measures and calls.

It was also mentioned that many initiatives would not have taken place at the national level because of the funding regime in the FPs. In some countries, national funding levels decrease with increasing technological readiness levels (TRLs), which makes it difficult for both industry and non-profit research to engage in such projects. The problem is that there still exists a large gap between the high TRLs and commercial application of a systems technology like the grid, creating still very high risks (which, by the way, has furthered the notion of societal readiness). The Framework Programme, in this respect is very attractive to research since it provides a 100% funding level irrespective of the TRL.

Another aspect was mentioned, and this regards the diversity of the countries, with their different history and different structure, especially how the grid operators are organized. It is seen as a source of creativity and learning potential to be exposed to a variety of solutions – which is unique to Europe –while the national focus would restrict the innovation scenarios.

5.5. Conclusion

The H2020 and partnership activities towards a single, smart European electricity grid are, in general, an industry-dominated activity within the electricity sector. The calls identified as relevant for this case study are designed as a cross-cutting technology-oriented programme to establish a cyber-physical system in an incremental development approach. Private sector participants are dominating and public sector research as research and development partners are involved, but public bodies are virtually absent. An integrated technological and market-oriented approach is adopted covering a broad range of technology readiness levels (from TRL3 to TRL9). This is also reflected in the balance of research and innovation actions (RIAs) and innovation actions (IAs) in H2020 and the strong focus on stakeholder integration in the partnership actions. Nevertheless, there may be a weakness in the sense that regulatory aspects and societal awareness and acceptance issues are not timely tackled or even underrepresented.

It is acknowledged that smart grids are not a goal per se but that their fundamental drivers are policy goals like climate protection and security of supply. So, the demand for smart grids comes from the wide-spread advent of intermittent renewable electricity production. H2020 has been successful with the provision of open tools and standards to avoid the dominance of private sector companies and to overcome barriers to the green transition related to incumbent sectoral structures. However, it was also made clear that the transformation of the electricity grid into a full-fledged smart grid has been an endeavour for generations and that the neglect of this fact may have led to disappointments when assessing the progress during the recent funding periods. Nevertheless, and additional push is seen in the current energy crisis, which could work as a turning point towards a massive increase in investment in smart grids to integrate renewables more quickly into the European electricity system.

5.6. References

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5.7. Annexes

5.7.1. Horizon 2020 project portfolio

Table 55. List of projects in the portfolio of case study Smart Grids.

Project-ID	Acronym	Full title	Type of action	CALL-ID
646555	ENERGISE	ICT-based ENERgy Grid Implementation – Smart and Efficient	CSA	H2020-LCE-2014-3
731220	IntEnSys4EU	INTEGRATED ENERGY SYSTEM - A PATHWAY FOR EUROPE	CSA	H2020-LCE-2016-SGS
824389	PANTERA	Pan European Technology Energy Research Approach	CSA	H2020-LC-SC3-2018-ES-SCC
646184	NOBEL GRID	New Cost Efficient Business Models for Flexible Smart Grids	IA	H2020-LCE-2014-3
646428	Flex4Grid	Prosumer Flexibility Services for Smart Grid Management	IA	H2020-LCE-2014-3
646469	P2P-SmarTest	Peer to Peer Smart Energy Distribution Networks (P2P-SmartTest)	IA	H2020-LCE-2014-3
646470	SmarterEMC2	Smarter Grid: Empowering SG Market Actors through Information and Communication Technologies	IA	H2020-LCE-2014-3
646476	EMPOWER	Local Electricity retail Markets for Prosumer smart grid pOWER services	IA	H2020-LCE-2014-3
646482	FLEXICIENCY	energy services demonstrations of demand response, FLEXibility and energy effICIENCY based on metering data	IA	H2020-LCE-2014-3
646531	UPGRID	Real proven solutions to enable active demand and distributed generation flexible integration, through a fully controllable LOW Voltage and medium voltage distribution grid	IA	H2020-LCE-2014-3
646568	FLEXMETER	Flexible smart metering for multiple energy vectors with active prosumers	IA	H2020-LCE-2014-3
646580	AnyPLACE	Adaptable Platform for Active Services Exchange	IA	H2020-LCE-2014-3
731148	INVADE	Smart system of renewable energy storage based on INtegrated EVs and bAtteries to empower mobile, Distributed and centralised Energy storage in the distribution grid	IA	H2020-LCE-2016-SGS
731205	WiseGRID	Wide scale demonstration of Integrated Solutions and business models for European smartGRID	IA	H2020-LCE-2016-SGS
731218	InteGrid	Demonstration of INTElligent grid technologies for renewables INTEgration and INTEractive consumer participation enabling	IA	H2020-LCE-2016-SGS

Project-ID	Acronym	Full title	Type of action	CALL-ID
		INTEroperable market solutions and INTErconnected stakeholders		
731232	GOFLEX	Generalized Operational FLEXibility for Integrating Renewables in the Distribution Grid	IA	H2020-LCE-2016-SGS
731249	SMILE	SMart IsLand Energy systems	IA	H2020-LCE-2016-SGS
731268	inteGRIDy	integrated Smart GRID Cross-Functional Solutions for Optimized Synergetic Energy Distribution, Utilization Storage Technologies	IA	H2020-LCE-2016-SGS
731289	InterFlex	Interactions between automated energy systems and Flexibilities brought by energy market players	IA	H2020-LCE-2016-SGS
773406	OSMOSE	Optimal System-Mix Of flexibility Solutions for European electricity	IA	H2020-LCE-2017-SGS
773430	CROSSBOW	CROSS BOrder management of variable renewable energies and storage units enabling a transnational Wholesale market	IA	H2020-LCE-2017-SGS
773505	EU-SysFlex	Pan-European system with an efficient coordinated use of flexibilities for the integration of a large share of RES	IA	H2020-LCE-2017-SGS
774407	FLEXITRANS TORE	An Integrated Platform for Incresed FLEXIbility in smart TRANSmission grids with STORage Entities and large penetration of Renewable Energy Sources	IA	H2020-LCE-2017-SGS
824330	INTERRFACE	TSO-DSO-Consumer INTERFACE aRchitecture to provide innovative grid services for an efficient power system	IA	H2020-LC-SC3-2018-ES-SCC
824414	CoordiNet	Large scale campaigns to demonstrate how TSO-DSO shall act in a coordinated manner to procure grid services in the most reliable and efficient way	IA	H2020-LC-SC3-2018-ES-SCC
863874	TRINITY	TRansmission system enhancement of regIoNal borders by means of IntellIgenT market technologY	IA	H2020-LC-SC3-2019-ES-SCC
863927	X-FLEX	Integrated energy solutions and new market mechanisms for an eXtended FLEXibility of the European grid	IA	H2020-LC-SC3-2019-ES-SCC
864048	FLEXIGRID	ENABLING FLEXIBILITY FOR FUTURE DISTRIBUTION GRID	IA	H2020-LC-SC3-2019-ES-SCC
864274	FARCROSS	FAcilitating Regional CROSS-border Electricity Transmission through Innovation	IA	H2020-LC-SC3-2019-ES-SCC
864283	ebalance-plus	Energy balancing and resilience solutions to unlock the flexibility and increase market options for distribution grid	IA	H2020-LC-SC3-2019-ES-SCC
864300	PlatOne	PLATform for Operation of distribution NEtworks	IA	H2020-LC-SC3-2019-ES-SCC
864319	PARITY	Pro-sumer AwaRe, Transactive Markets for Valorization of Distributed flexibilITY enabled by Smart Energy Contracts	IA	H2020-LC-SC3-2019-ES-SCC
864334	EUniversal	MARKET ENABLING INTERFACE TO UNLOCK FLEXIBILITY SOLUTIONS FOR COST-EFFECTIVE MANAGEMENT OF SMARTER DISTRIBUTION GRIDS	IA	H2020-LC-SC3-2019-ES-SCC
864537	FEVER	Flexible Energy Production, Demand and	IA	H2020-LC-SC3-2019-

Project-ID	Acronym	Full title	Type of action	CALL-ID
		Storage-based Virtual Power Plants for Electricity Markets and Resilient DSO Operation		ES-SCC
864579	FLEXIGRID	Interoperable solutions for implementing holistic FLEXIbility services in the distribution GRID	IA	H2020-LC-SC3-2019-ES-SCC
957739	OneNet	One Network for Europe	IA	H2020-LC-SC3-2020-EC-ES-SCC
691405	SmartNet	Smart TSO-DSO interaction schemes, market architectures and ICT Solutions for the integration of ancillary services from demand side management and distributed generation	RIA	H2020-LCE-2015-3
691777	FutureFlow	Designing eTrading Solutions for Electricity Balancing and Redispatching in Europe	RIA	H2020-LCE-2015-3
691800	MIGRATE	Massive InteGRATion of power Electronic devices	RIA	H2020-LCE-2015-3
731125	PENTAGON	Unlocking European grid local flexibility trough augmented energy conversion capabilities at district-level	RIA	H2020-LCE-2016-SGS
731155	Storage4Grid	Storage4Grid	RIA	H2020-LCE-2016-SGS
731187	BAoBaB	Blue Acid/Base Battery: Storage and recovery of renewable electrical energy by reversible salt water dissociation	RIA	H2020-LCE-2016-SGS
731211	SABINA	SmArt BI-directional multi eNergy gAteway	RIA	H2020-LCE-2016-SGS
731231	FHP	Flexible Heat and Power, Connecting heat and power networks by harnessing the complexity in distributed thermal flexibility.	RIA	H2020-LCE-2016-SGS
731239	EnergyKeeper	Keep the Energy at the right place!	RIA	H2020-LCE-2016-SGS
731285	SHAR-Q	Storage capacity sharing over virtual neighbourhoods of energy ecosystems	RIA	H2020-LCE-2016-SGS
771066	DOMINOES	Smart Distribution Grid: a Market Driven Approach for the Next Generation of Advanced Operation Models and Services	RIA	H2020-LCE-2017-SGS
773708	INTERPLAN	INTEgrated opeRation PLAnning tool towards the Pan-European Network	RIA	H2020-LCE-2017-SGS
773715	RESOLVD	Renewable penetration levered by Efficient Low Voltage Distribution grids	RIA	H2020-LCE-2017-SGS
773717	UNITED-GRID	Integrated cyber-physical solutions for intelligent distribution grid with high penetration of renewables	RIA	H2020-LCE-2017-SGS
773839	PLANET	Planning and operational tools for optimising energy flows and synergies between energy networks	RIA	H2020-LCE-2017-SGS
773897	Plan4Res	SYNERGISTIC APPROACH OF MULTI-ENERGY MODELS FOR AN EUROPEAN OPTIMAL ENERGY SYSTEM MANAGEMENT TOOL	RIA	H2020-LCE-2017-SGS
773909	FLEXCoop	Democratizing energy markets through the introduction of innovative flexibility-based demand response tools and novel business and market models for energy cooperatives	RIA	H2020-LCE-2017-SGS

Project-ID	Acronym	Full title	Type of action	CALL-ID
773960	DELTA	Future tamper-proof Demand rEsponse framework through seLf-configured, self-opTimized and collAborative virtual distributed energy nodes	RIA	H2020-LCE-2017-SGS
774145	Net2DG	Leveraging Networked Data for the Digital electricity Grid	RIA	H2020-LCE-2017-SGS
774309	MAGNITUDE	Bringing flexibility provided by multi energy carrier integration to a new MAGNITUDE	RIA	H2020-LCE-2017-SGS
774392	E-LOBSTER	Electric LOsses Balancing through integrated STorage and power Electronics towards increased synergy between Railways and electricity distribution networks	RIA	H2020-LCE-2017-SGS
774431	DRIVE	Demand Response Integration tEchnologies: unlocking the demand response potential in the distribution grid	RIA	H2020-LCE-2017-SGS
774478	eDREAM	eDREAM - enabling new Demand REsponse Advanced, Market oriented and Secure technologies, solutions and business models	RIA	H2020-LCE-2017-SGS
774500	TDX-ASSIST	Coordination of Transmission and Distribution data eXchanges for renewables integration in the European marketplace through Advanced, Scalable and Secure ICT Systems and Tools	RIA	H2020-LCE-2017-SGS
774613	SOGNO	Service Oriented Grid for the Network of the Future	RIA	H2020-LCE-2017-SGS
774629	Spine	Open source toolbox for modelling integrated energy systems	RIA	H2020-LCE-2017-SGS
863819	FlexPlan	Advanced methodology and tools taking advantage of storage and FLEXibility in transmission and distribution grid PLANning	RIA	H2020-LC-SC3-2019-ES-SCC
863876	FLEXGRID	A novel smart grid architecture that facilitates high RES penetration through innovative markets towards efficient interaction between advanced electricity grid management and intelligent stakeholders	RIA	H2020-LC-SC3-2019-ES-SCC
863922	PlaMES	Integrated Planning of Multi-Energy Systems	RIA	H2020-LC-SC3-2019-ES-SCC
864276	TradeRES	Tools for the Design and modelling of new markets and negotiation mechanisms for a ~100% Renewable European Power Systems	RIA	H2020-LC-SC3-2019-ES-SCC
864298	ATTEST	Advanced Tools Towards cost-efficient decarbonisation of future reliable Energy SysTems	RIA	H2020-LC-SC3-2019-ES-SCC
864337	Smart4RES	Next Generation Modelling and Forecasting of Variable Renewable Generation for Large-scale Integration in Energy Systems and Markets	RIA	H2020-LC-SC3-2019-ES-SCC
864360	INTERPRETER	Interoperable tools for an efficient management and effective planning of the electricity grid	RIA	H2020-LC-SC3-2019-ES-SCC
864459	TALENT	COST EFFECTIVE TECHNOLOGICAL DEVELOPMENTS FOR ACCELERATING ENERGY TRANSITION	RIA	H2020-LC-SC3-2019-ES-SCC
864496	ComBioTES	Compact bio-based thermal energy storage for buildings	RIA	H2020-LC-SC3-2019-ES-SCC

5.7.2. Tables of Horizon 2020 calls analysed

Table 56. List of H2020 calls in the case study Smart Grids.

CALL-ID (eCorda)	Number of analysed projects
H2020-LCE-2014-3	10
H2020-LCE-2015-3	3
H2020-LCE-2016-SGS	15
H2020-LCE-2017-SGS	20
H2020-LC-SC3-2018-ES-SCC	3
H2020-LC-SC3-2019-ES-SCC	19
H2020-LC-SC3-2020-EC-ES-SCC	1
Total projects analysed	**71**

5.7.3. Overview of related ERA-NETs

Table 57. List of ERA-NET SES joint call projects covered in the case study Smart Grids.

Project acronym	Project title	Participating countries
Projects of the SES Joint Call 2020		
AI-flex	Autonomous AI for cellular energy systems in-creasing flexibilities provided by sector coupling and distributed storage	Austria, Germany
AISOP	AI-assisted grid situational awareness and operational planning	Germany, Switzerland
BioLens	BioLens	Denmark, Sweden
DIEGO	Digital energy path for planning and operation of sustainable grid, products and society	Austria, Germany, Israel, Poland
DigiCiti	Digital energy solutions promoting social innovation, circular economy, climate change mitigation and urban resilience	Austria, Sweden
Digicities	Urban Digital Layers to Support the Energy Transition of Cities	Austria, Switzerland
DigIPlat	Digital Solutions for Interoperability of Flexibility Platforms	Austria, Germany, Switzerland
DIWIEN	Digitalization of water supply infrastructure to optimize the Water-Energy Nexus	Austria, Czechia, Turkey
DoRES	Deployment of smart renewable energy communities	Latvia, Czechia
FinSESCo	Fintech Platform Solution for Sustainable Energy System Interacting and Contracting boosting energy saving and renewable energy	Austria, Germany, India, Romania, Spain
GAMES	Grid Aware Mobility and Energy Sharing	Austria, Israel, Switzerland
OpenGIS4ET	Open Geographic Information System for Energy Transition	Switzerland, Austria, Denmark, Germany
ReliaREN-Pro	Reliability of Long Term Renewable Energy Production based on PV Technologies	Austria, Germany, Turkey
RESili8	Resilience for Cyber-Physical Energy Systems	Austria, Germany,

Project acronym	Project title	Participating countries
		Netherlands, Sweden
Projects of the SES Joint Call 2019		
ADHERE	Development of Advanced Composite Pressure Vessels for Hydrogen Storage	India, Sweden, Turkey, Israel, South Africa
AISTOR	SMART AI BASED STORAGE SYSTEM	Turkey, Romania
Bio-Nrg-Store	Bio-Based Phase Change Materials in Lignocellulose Matrix for Energy Store in Buildings	Turkey, Austria, Italy, Sweden
CCP	CrossChargePoint - Integrated Multi-Energy Storages Coupling the Power Network to the Transportation	Germany, Austria, Israel
DEVISE	Diverse Energy Vectors Integration for Storage of Energy	India, Italy, Norway, Sweden
H2 CoopStorage	Development of tools enabling the deployment and the management of a multi-energy (electric, heat, hydrogen) Energy Community integrating hybrid storage	Belgium, Iceland, Norway
HED-LiS	High Energy Density Lithium Sulfur Batteries for Stationary Applications	Turkey, Finland, Norway
I-GReta	Intelligent FIWARE-based Generic Energy Storage Services for Environmentally Responsible Communities and Cities	Germany, Austria, Romania, Sweden
IFAISTOS	Intelligent electroFuel production for An Integrated STOrage System	Italy, Sweden
MESH4U	Multi Energy Storage Hub For reliable and commercial systems Utilization	Poland, Italy, Germany, Switzerland
NewSETS	New energy storages promoting sustainable energy transition in societies	Finland, Sweden
P2T	Power-2-Transport	Sweden, Switzerland
USC-FlexStore	Underground Sun Conversion – Flexible Storage	Austria, Switzerland
Projects of the SES Joint Call 2018		
AGRO-SOFC	Sector coupling with SOFC technology in the agro-industry agro-industry	Austria, Spain
ANM4L	Active Network Management For All	Sweden, Hungary, Germany
BEYOND	Blockchain based Electricity trading for the integration Of National and Decentralized local markets	Norway, Austria, Ireland, Spain
CLUE	Concepts, Planning, Demonstration and Replication of Local User-friendly Energy Communities	Austria, Germany, Denmark, Sweden, United Kingdom
DiGriFlex	Real-Time Distribution Grid Control and Flexibility Provision under Uncertainties	Switzerland, Italy
DISTRHEAT	Digital Intelligent and Scalable conTrol for Renewables in HEAting neTworks	Italy, Sweden
EPC4SES	EPC based Digital Building Twins for Smart Energy	Austria, Germany,

Project acronym	Project title	Participating countries
	Systems SES	Norway, Spain
EVA	Optimization of regional infrastructures for the transition to Electric and Connected Autonomous Vehicles	Switzerland, Italy, Austria
EVCHIP	Electric Vehicles Charging Platform for Community Demand Response Aggregators	Ireland, Italy
Flexi-Sync	Flexible energy system integration using concept development, demonstration and replication	Sweden, Austria, Germany, Spain
FlexSUS	Flexibility for Smart Urban Systems	Denmark, Sweden, Netherlands
HEATflex	HEATflex	Austria, Denmark
HONOR	Holistic flexibility market integration of cross sectoral energy sources	Germany, Denmark, Sweden, Norway
Multiportgrid	Cross-Sectoral Energy Control through Interconnected Microgrids by Multiport Converter	Sweden, Italy, Spain
PIGergy	A novel means of unleashing the energy potential of pig waste	Ireland, Italy
R2EC	Regional Renewable Energy Cells	Austria, Norway, Belgium
REDAP	Regional Energy Demand Analysis Portal	Austria, Ireland, Sweden
REgions	Ancillary services of regions with high shares of renewable energies for regional, interregional and European markets	Austria, Germany, France
SIES 2022	Smart Integrated Energy Systems 2022	Scotland, Turkey, Spain
SONDER	Service Optimization of Novel Distributed Energy Regions	Austria, Sweden, Switzerland
SuperP2G	Synergies Utilising renewable Power REgion-ally by means of Power To Gas	Denmark, Italy, Netherlands, Germany, Austria
TOP-UP	TOP-down energy projects as catalysts for bottom-UP local energy initiatives.	Netherlands, Denmark
ZEHTC	Zero Emission Hydrogen Turbine Center	Sweden, Italy
Projects of the SG+ Joint Call 2017		
ACES	Adaptive Control of Energy Storage	Sweden, Norway, Germany
RELflex	Renewable Energy and Load Flexibility in Industry	Germany, Poland
SMART-MLA	Multi-Layer Aggregator Solutions to Facilitate Optimum Demand Response and Grid Flexibility	Turkey, Denmark, Sweden, Romania, Norway
Concluded Projects / Joint Calls 2015 and 2016		
E-REGIO	Smart Community Markets	Norway, Sweden
EMBS	Energy Management Building Set	Austria, Germany
FISMEP	FIWARE for Smart Energy Platform	Germany, Romania, Sweden

Project acronym	Project title	Participating countries
LarGo!	Large-Scale Smart Grid Application Roll-Out	Austria, Germany, Sweden
m2M-Grid	From micro to Mega-GRID: Interactions of micro-grids in active distribution networks	France, Sweden, Netherlands
MatchIT	Efficient demand and supply matching by incentivizing end-users in buildings	Netherlands, Sweden
NEMoGrid	New Energy Business Models in the Distribution Grid	Sweden, Switzerland, Germany
RestoreGrid4RES	Strategies and operator tools for grid restoration with massive renewable energy sources	Austria, Germany
SmartLoad	Smart Meter Data Analytics for Enhanced Energy Efficiency in the Residential Sector	Germany, Switzerland
CALLIA	Direct and automated cooperative market for grid operators on national and transnational level for integration of local flexibility	Germany, Turkey, Austria, Belgium
CERA-SG	Cost-efficient data collection and analysis for smart grid and revenue assurance	Germany, Romania
CESEPS	Demand-oriented design of smart energy products and services for local energy grids and markets	Netherlands, Austria
CloudGrid	Transnational CLOUD for Interconnection of Demonstration Facilities for Smart GRID Lab Research & Development	Sweden, Norway, Switzerland, Latvia
DCSmart	Integrating smart DC distribution grid technologies	Netherlands, Germany, Switzerland
DeCAS	Technology and market integration for coordinated ancillary services covering different voltage levels	Germany, Slovenia, Austria, Finland
EPR	Pattern recognition for optimized grid parameter management	Sweden, Norway, Turkey
GReSBAS	Gamification for energy management in buidlings	Turkey, Portugal
Grid-Friends	Energy management system with demand response for grid-friendly quasi-autarkic energy cooperatives	Netherlands, Germany
MATCH	Transnational cloud for interconnection of demonstration facilities for smart grid lab research & development	Denmark, Norway, Latvia
MIDAS	Multi-input intelligent distribution automation system	Turkey, Austria, Sweden
Poweralliance	From local peak shaving to regional load shaping, a transnational demonstative initiative	Switzerland, Germany, Austria
ReFlex	Replicability concept for flexible smart grids considering technical, business and social design	Austria, Sweden, Switzerland, Germany
REstable	Virtual power plant for renewables-based ancillary services	France, Germany, Portugal
RIGRID	Interactive applications for optimal planning and operation of energy infrastructure in rural areas	Germany, Poland
SMARES	Configurable energy management system for renewable	Spain, Portugal

Project acronym	Project title	Participating countries
	power plants and smart grids	
SmartGuide	Planning and operation principles for cost-efficient distribution grid management	Germany, Scotland, Portugal, Norway
Solar Charge	Utilizing batteries in electric vehicles to store solar electricity	Sweden, Norway
uGRIP	Distribution level microgrid concept integrating distributed generation sources and consumer participation	Croatia, Denmark, Germany
VOLATILE	Voltage control on the transmission grid using wind power at other voltage levels	Sweden, Denmark

6. Case study 6: Offshore wind

6.1. Summary

The case study identifies and analyses relevant actions related to the development of a specific renewable energy source, offshore wind energy, in Horizon 2020.

The case study shows that the work programs have established a portfolio of interventions in the offshore wind energy field which provided important foundations for progress towards EU and international policy priorities and objectives related to the green transition. The case study shows that the Framework Programme contributed to a) an increase of publicly available knowledge and evidence on a variety of innovations in offshore wind, b) Technical innovations enabling future cost reduction and upscaling: new designs for offshore wind substructures; new systems for monitoring operations and identifying component failure, or servicing wind farms; progress on meshed offshore networks c) Upskilling and training d) the diffusion of offshore wind to a wider geography.

During the time of Horizon 2020, the offshore wind sector saw a significant decrease in the cost of offshore wind energy; however, this cannot be attributed to Horizon 2020 interventions to a large degree because most projects were still active and being delivered while the sector experienced a drop in the price of offshore wind.

The following enabling factors were identified as contributing to the effectiveness of the portfolio: 1) Application-oriented projects, 2) Closeness to sectoral priorities through dialogue with industry and research stakeholders enabled by the European Technology Platform (ETIP Wind), 3) A focus on cross-country cooperation.

The portfolio provides an enabling basis to continue interventions under Horizon Europe, with a renewed focus on the two key areas of floating offshore wind and integration of offshore wind with the electricity grid and the rest of the energy system.

6.2. Introduction and overview

6.2.1. Objectives

The case study identifies and analyses relevant actions related to offshore wind energy research and innovation under the Horizon 2020 Framework Programme and respective partnerships (i.e. Offshore Wind ERA-NETs). It provides an assessment of the implementation of the Horizon 2020 funded projects in this area and shows how the results and outcomes contribute to the overarching goals of Horizon 2020 and whether Horizon 2020 provided a strong basis for developing and progressing offshore wind-related actions under Horizon Europe. Against this background, the main objective of this case study is to analyse to which extent Horizon 2020 actions enabled an effective approach for supporting the development of Offshore Wind innovation that can be further scaled up in Horizon Europe.

6.2.2. Methodology and case study structure

The analysis comprised 18 Horizon 2020 topics. The time horizon covered with the analysis is 2014/2020. The number and type of instruments analyzed are 8 RIAs, 7 IAs, 1 CSA, 1 ERA-NET and 2 SME Instruments. An overview is provided in the Annex of this case study.

The analytical approach encompassed a thorough analysis of work programmes, relevant call texts etc., and strategic documents related to Offshore Wind (e.g., Set Plan Strategic Plan, European Wind Initiative, Set Plan Implementation Plan for Offshore Wind). We then identified relevant project actions in Horizon 2020 based on a key-word search of topics in the work programme. For the identified projects, relevant data as available from Cordis/Corda have been compiled and analyzed and complemented by additional sources like project websites.

In addition to the project data analysis, we performed 4 interviews with 6 relevant stakeholders. The interviewees comprised representatives of thematic experts involved in the European strategic and policy processes, project beneficiaries and Offshore Wind innovation experts. The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus.

For synthesizing the analysis, we triangulated and analyzed the findings in relation to the evaluation questions.

6.3. Synthesis of evidence

6.3.1. A Green Transition with Offshore wind

Offshore Wind is a growing source of low-carbon renewable energy used to meet global commitments for the decarbonisation of energy systems. Production and use of energy accounts for 75% of carbon emissions in the EU. Therefore, renewable energy generally and offshore wind specifically have prominent roles in EU green transition policy, such as the EU Green Deal.

One of the major challenges facing Europe is to make its energy system clean, secure and efficient while ensuring EU industrial leadership in low-carbon energy technologies. When Horizon 2020 was launched, the EU aimed to reduce its GHG emissions by 20% on 1990 levels by 2020 and aimed to achieve a further reduction to 80-95% by 2050. Horizon 2020 established Societal Challenge 3 to respond to the need to reduce fossil fuel dependency in the face of increasingly scarce resources, increasing energy needs, and climate change. To address the needs, the specific objective for the Energy Challenge established in the legal base of H2020 was to “make the transition to a reliable, affordable, publicly accepted, sustainable and competitive energy system”.

Since the conception of the Societal Challenge, “Secure, clean and efficient energy” (SC3), several international and European strategies and initiatives have emerged that have changed the overarching reference framework for SC3, particularly the Paris Agreement and, most recently, the European Green Deal. According to interviews, the European Green Deal marked another major milestone in the evolution of European and international climate and energy policy, progressing from, inter alia, the Rio Conference, the Kyoto Protocol, and COP21. The European Green Deal introduced more ambitious targets for the energy transition while simultaneously marking a radical shift within European policymaking as its objectives were enshrined into the European Climate Law.

Under the European Green Deal, the European Commission adopted a set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030. The European Green Deal expects to transform Europe into a fair and prosperous society with a modern, resource-efficient and competitive economy with no net emissions of greenhouse gases in 2050. To decarbonise the European energy system, land-based and offshore renewables are envisaged to become the main energy source.

Offshore renewable energy is one of the most promising routes to increase future power generation in the coming years in a way that meets Europe’s decarbonisation objectives and the expected rise in electricity demand in an affordable manner. Offshore wind capacity in Europe is set to increase significantly, and this increase would represent a paradigm shift in the European energy system and require a modern infrastructure to seamlessly integrate the power of offshore resources into the energy system via the grid to onshore. As such, Horizon 2020 has invested in offshore wind Research & Innovation.

6.3.2. Strategic policy priorities related to Offshore Wind

In 2014, when the first Horizon 2020 Work Programme was launched, it was deemed that offshore wind had a high cost compared to other renewable energy sources, such as onshore wind and solar PV, due to it being a young technology that started industrial level development only a few years previously. As a result, it was deemed to have a large potential for cost reduction through economies of scale and technological learning.

The Strategic Energy Technology Plan (SET) is a key European initiative launched in 2007 aimed at accelerating the development and deployment of low-carbon technologies through cooperation amongst EU countries, companies, research institutions, and the EU. Under the SET Plan, a European Wind Initiative (EWI)[133] was created in 2009 as a long-term, large-scale programme for improving and increasing funding to wind energy R&I in the EU. It was estimated that the EWI would require a budget of 6 bn Euros for the period 2010-2020, more than half of which to be provided by the wind power industry and about 30% by European funds (Framework Programme 7 and Horizon 2020). The objectives of the European Wind Initiative were to:

- maintain Europe's technology leadership in onshore and offshore wind power
- make onshore wind the most competitive energy source by 2020, with offshore following by 2030
- achieve a 20% share of wind energy in EU total electricity consumption by 2020
- create 250,000 new skilled jobs in the EU by 2020

In 2015, an Integrated SET Plan was published focusing on ten actions structured around the Energy Union R&I priorities with the of accelerating the transformation of the European energy system making it more sustainable, secure and competitive as a fundamental enabler of a low carbon economy. The SET Plan includes Implementation Plans for all the key energy technologies identified and includes an Implementation Plan for offshore wind, first released in 2018.

A working group on offshore wind energy helps to coordinate SET Plan countries' R&I agendas for offshore wind and promotes increased collaboration between national research activities. It is supported by the European Technology Innovation Platform (ETIP) Wind, European Energy Research Alliance (EERA) JP Wind and SETWind project.

The main elements of the first 2018 Implementation Plan were targets for reducing the cost of floating and bottom fixed offshore wind and nine R&I priority actions, namely:

- System integration
- Wind energy offshore balance of plant
- Floating offshore wind
- Wind energy operations and maintenance
- Wind energy industrialisation
- Wind turbine technology
- Basic wind energy sciences
- Ecosystem and social impact
- Human capital agenda

[133] http://www.ewea.org/fileadmin/files/library/publications/reports/EWI_2013.pdf

New Implementation Plans were published in 2020 and 2022, consisting of an updated version of targets and priority actions. The latest plan produced in 2022 aimed at achieving the required annual installed capacity of wind power and grids towards 2030 to achieve the upper target of 450 GW offshore wind by 2050.

In 2020 the European Union released the 'Offshore Renewable Energy Strategy', which proposes an increase of the EU's offshore wind capacity from 12GW to at least 60GW by 2030 and 300GW by 2050. Alongside establishing ambitious new targets, the Offshore Wind Strategy recognises the successes of recent years during the time of H2020:

"It is a story of undisputed European technological and industrial leadership: European laboratories and industries are rapidly developing a range of other technologies to harness the power of our seas for producing green electricity, from floating offshore wind to ocean energy technologies such as wave or tidal, floating photovoltaic installations and the use of algae to produce biofuels."

Whilst offshore wind energy is a mature technology, the strategy calls for further R&I efforts to contribute to the optimisation of existing manufacturing processes in sectors such as large-scale blade production. The strategy proposes to make offshore renewable energy a core component of Europe's energy system, and it calls for an increase in efforts from Member States to create a framework facilitating businesses and investors to deploy offshore wind and relevant grid infrastructure.

6.3.3. Horizon 2020 programming related to Offshore Wind

6.3.3.1. Horizon 2020 Work Programmes related to Offshore Wind

Offshore wind objectives have been present in all three biannual work programmes of Horizon 2020, mainly in the programme part of Societal Challenge 3 – Secure, clean and efficient energy, with some contributions also in Societal Challenge 2 - Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy, and in the Cross-Cutting Work Programme of 2018-2020.

All SC3 Work Programmes included calls on the development and demonstration of various renewable energy technologies aimed at producing new knowledge and more efficient and cost-competitive energy technologies, including their supply chains. It was emphasised that renewable energy technologies should not represent a risk to society and that better scientific understanding would inform strategic choices concerning future energy technologies and their integration into the future energy system. Activities funded should assist in readying technologies, the associated business cases, and industry for these markets and consider all supply-side issues of relevance, including the evolving requirements of the grids.

The **Work Programme 2014-2015** called for the development and demonstration of specific **offshore wind innovations aimed at reducing the cost of offshore wind energy and improving the understanding of risk**, including:

- Developing control strategies and systems for large rotors and wind farms
- Developing new substructure concepts, including floating platforms for water depths of more than 50m
- Developing integrated offshore systems with a significant lower mass per unit power installed to reduce production, installation and Operation & Maintenance (O&M) costs
- Demonstrating and testing new nacelle and rotor prototypes with lower mass and material intensity
- Demonstrating innovative bottom-fixed substructure concepts for water depths of 30 to 50m capable of reducing costs
- Demonstrating innovative floating wind turbine concepts

The Work Programme also called for the **coordination of research efforts** of the participating Member States, Associated States and Regions to accelerate the time to market technology solutions to decarbonise the energy system. This included a crucial role for SMEs in developing technology solutions to decarbonise and make more efficient the energy system while enhancing **SME profitability and growth performance**.

The **Work Programme 2016-2017** called for the development and demonstration of specific **offshore wind innovations** that can improve the efficiency of operating wind farms and increase the understanding of their environmental impact. Specific challenges requiring innovation included:

- Developing advanced control strategies that treat the entire wind plant as a controls optimization problem to optimize energy capture for individual assets with the wind-turbine-centric controls and to develop a better understanding of the wind resources and better wind forecasting methods. This would lead to advanced operation of wind turbines and farms, reducing the failure rate and therefore resulting in less O&M.

- Developing a better understanding of the impact of wind energy on the environment. This would be used in developing mitigating strategies or alternative solutions to increase public acceptance of wind energy and shorten consenting procedures. Participation of NGOs was encouraged.

- Developing new O&M and control concepts for offshore wind farms to reduce the cost of operation. Participation of wind turbine manufacturers and large wind farm operators was expected.

- Demonstrate and construct a full-scale>10 MW wind turbine (TRL 7) and provide proof of a significant cost reduction potential

In a context of growing demand for resources and competition for land use, The Work Programme also called for solutions able to find synergies between different **uses of offshore space**, such as new markets, services and products using resource-efficient and integrated approaches across economic sectors. These actions were supported by the **Work Programme of Societal Challenge 2** - Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy – under the area of Blue Growth.

As in the previous Work Programme, the role of SMEs in developing solutions was emphasised.

The **Work Programme 2018-2020** called for a strengthening of the EU leadership on renewables and a crucial role of cost reduction in the adoption of new technologies, as set out in the SET Plan. It focused on:

- Developing and validating new manufacturing, installation, operation and maintenance techniques, including the use of new materials and involving considerations on the whole value chain, including dismantling, recycling and retrofitting procedures

- Developing monitoring systems (sensors, fault detection and communication systems) for offshore, enabling predictive and preventive O&M processes

- Demonstrating floating offshore wind innovations (blades, floaters, moorings, electrical subsystems and cabling, monitoring systems) in view of scaling-up power rating to >10 MW

- Developing better knowledge of basic wind energy science to contribute to the understanding of offshore wind energy generation and cost reductions

Alongside calling for technological advances, the Work Programme also called for coordination actions supporting the implementation of the Strategic Energy Technology Plan (SET). In particular, it called for strengthened partnerships among SET Plan countries and the stakeholders from both the industrial (including the European Technology and Innovation Platforms, ETIPs) and research communities (including the European Energy Research Alliance, EERA). The targets adopted by the SET Plan are to be implemented for offshore wind through the Implementation Plan, and coordination is required to achieve that.

Finally, also in 2018-2020, a **Cross-Cutting Work Programme** was presented, which included, amongst others, actions stimulating low-carbon energy innovation. For offshore wind innovation, funding addressing the following areas was made available:

- Offshore renewable energy power generating systems and grid infrastructure

- Assessment of the feasibility of connecting electrolysers for the production of hydrogen to a production site of renewable sources of energy such as offshore wind

6.3.3.2. Summary of strategic policy priorities

The analysis of the Work Programmes and the projects showed that distinct pathways to impact can be identified that connect the activities carried out within the work programme with identifiable effects (outcomes).

The **coordination and collaboration** pathway highlights the importance of collaboration between different stakeholders involved with offshore wind innovation (university and research centres, industry and the public sector) across the EU and internationally. The ambition was to facilitate the coordination of research efforts between companies and researchers and between different countries to accelerate the development of innovations.

The **knowledge and capacity building** pathway emphasises the creation of knowledge on technological aspects relating to offshore wind and its environmental, social and economic benefits or challenges. New knowledge and upskilled workers also lead to wider capacity building in offshore wind in the private or research sectors and to the diffusion of knowledge, contributing to sustaining European leadership in offshore wind innovation.

The **market & business** pathway focuses on the main aim to reduce the cost of offshore wind energy generation through a reduction of the cost of installing, operating and maintaining offshore wind farms. Decreased costs would lead to electricity from offshore wind being able to compete on a level playing field with other sources of energy, to increased investments in the deployment of offshore wind and its wider adoption. This pathway also highlights the role of activities in strengthening the European offshore wind industry, including SMEs.

The **technology and innovation** pathway emphasizes the importance of increasing the reliability of offshore wind technologies, improving the efficiency of O&M of plants and systems, and increasing the energy output of turbines. It also focuses on developing new and improved solutions for deploying offshore wind in deeper seas and for multiple uses of offshore platforms.

The **policy and standards** pathway emphasizes the need to facilitate the adoption of new technical standards following technical developments, including for building offshore wind infrastructure connecting offshore farms to the onshore grid.

6.3.4. Project portfolio characteristics

The project portfolio of this case study comprises 32 projects, of which 11 projects are still active. 2 of these projects will be finished by the end of 2022, whilst the remaining ones have varying end dates, with the earliest being February 2023 and the latest September 2026.

6.3.4.1. Participation by stakeholder types in Offshore Wind H2020 projects

Table 58. Type of organisations in Case Study Offshore Wind Energy.

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1000)
		Nb	Share (%)	EUR (1000)	Share (%)	
HES	25	71	17%	59,682	19%	840.6
OTH	9	13	3%	10,145	3%	780.4
PRC	31	271	66%	202,528	65%	747.3
PUB	6	6	1%	3,162	1%	527.0
REC	24	52	13%	33,748	11%	649.0
Total (All types)	**32**	**413**	**100%**	**309,265**	**100%**	**748.8**

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

Source: eCorda, own calculation

The sum of EC's net contribution is 309m Euros, of which 65% has been allocated to private companies, 19% to higher education institutions, 11% to research organisations, 1% to public bodies and 3% to other organisations. Compared with the average for Societal Challenge 3 Energy (SC3), the funding for private organisations in the area of offshore wind energy is high (65% compared to 50%), indicating a very high relevance for the private sector of this area compared to other Energy areas. Compared with all other Green Transition areas considered in this study (SC2 to SC5), the portfolio of offshore wind energy projects has the highest share of funding for private sector organisations, followed closely by Transport (SC4) with an average of 62%.

6.3.4.2. Participation by type of instruments in Offshore Wind H2020 projects

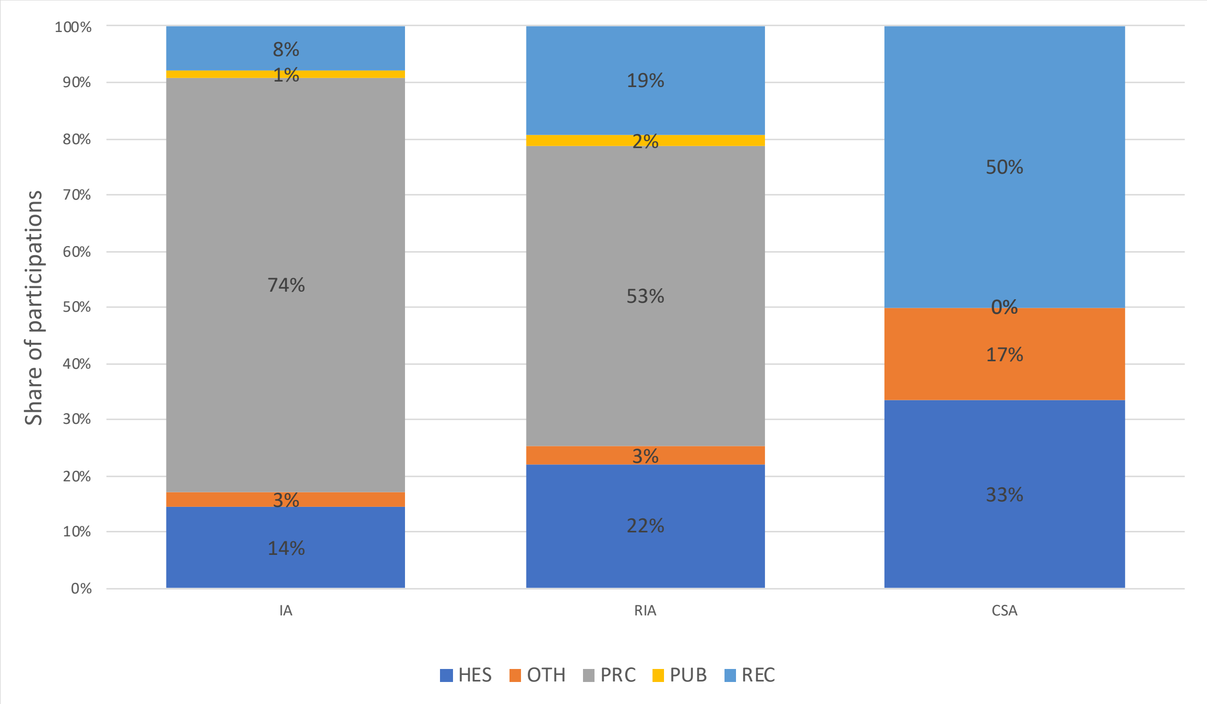

Figure 231 Share (%) of participants by type of action/instrument.

Source: eCorda, own calculation

With a 78% share of funding allocated to Innovation Actions (IA), the Offshore Wind case study portfolio is characterised by a high degree of application orientation and a limited representation of CSAs (0.3%) compared with the aggregated Green Transition project portfolio, in which the share of IA is at 47,3% and the share of CSA at 7,4% of allocated funding. The portfolio highlights commitment to innovation and commercialisation of research results, which have also been confirmed in the interviews. Within the portfolio of instruments, specific patterns of participation of actor types occur. Both IAs and RIAs are densely populated with private companies, whereas CSAs see a high share of research organisations and higher education institutions (for a combined total of 83%).

6.3.4.3. Participation by countries in Offshore Wind H2020 projects

Geographically, the eCorda statistics show that Horizon 2020 opened up the participation of associated countries and third countries in terms of the number of projects they have been involved with. The United Kingdom has been actively involved in H2020 projects participating in 24 out of 32 projects; Associated Countries (excluding the UK) have participated in 17 out of 32 projects, whilst third countries only in 3 out of 32 projects. However, the total budget for this group represents only 17.2% of all EU contributions (of which only 5.7% is allocated to the United Kingdom). The largest share of the budget was allocated to EU-14 countries (77.5%), and EU-13 countries had a very low rate of participation, being involved in only 4 projects with a share of the budget of 0.5%, which is lower than the average for both Energy (SC3) and all other Horizon 2020 Green Transition projects.

Table 59. Groups of countries (of supported organisations) in Case Study Offshore Wind.

Group of country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Number of countries
		Nb	Share (%)	EUR (1,000)	Share (%)		
H2020-EU27	31	325	78,7%	256 037	82,8%	787,8	18
EU-14	*31*	*320*	*77,5%*	*254 503*	*82,3%*	*795,3*	*13*
EU-13	*4*	*5*	*1,2%*	*1 534*	*0,5%*	*306,8*	*5*
H2020-associated (exclude UK)	17	38	9,2%	35 559	11,5%	935,8	2
United Kingdom	24	47	11,4%	17 669	5,7%	375,9	1
Third Countries	3	3	0,7%	0	0,0%	0,0	2
All-countries	**32**	**413**	**100,0%**	**309 265**	**100,0%**	**748,8**	**23**

Source: eCorda, own calculation

The country present across the greatest number of projects was the United Kingdom, involved in 24 out of 32 H2020 offshore wind projects and the third for the number of participations (47). However, its share of the budget was small in relation to its participation (only 6%).

The second and third most active countries were Spain (21 projects) and Germany (20 projects), with a respective share of the budget of 16% and 12%. The country receiving the highest amount of funding was Denmark, with a 19% share of the budget and the highest EC contribution per participant. The Netherlands also had a substantial share of the budget (12%), followed by Norway (11%).

Table 60. Top countries (of supported organisations) in projects of the Case Study Offshore Wind.

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Order
		Nb	Share (%)	EUR (1,000)	Share (%)		
United Kingdom	24	47	11,4%	17 669	6%	375,9	1
Spain	21	78	18,9%	50 466	16%	647,0	2
Germany	20	67	16,2%	36 226	12%	540,7	3
Denmark	17	39	9,4%	57 908	19%	1 484,8	4
France	16	27	6,5%	24 652	8%	913,0	5
Netherlands	16	40	9,7%	36 149	12%	903,7	6
Norway	15	33	8,0%	33 289	11%	1 008,7	7
Belgium	10	13	3,1%	7 447	2%	572,9	8
Italy	7	18	4,4%	8 016	3%	445,3	9
Ireland	6	8	1,9%	2 725	1%	340,6	10
Austria	5	5	1,2%	1 978	1%	395,7	11
Portugal	4	12	2,9%	15 082	5%	1 256,9	12
Switzerland	4	5	1,2%	2 271	1%	454,1	13
Sweden	4	9	2,2%	10 777	3%	1 197,5	14
Greece	2	3	0,7%	2 448	1%	815,9	15
United States	2	2	0,5%	0	0%	0,0	16

Source: eCorda, own calculation

The network analysis based on the number of collaborations among organisations from each pair of countries in the projects included in this case study confirms that there was a high intensity of collaboration among a few core countries, predominantly from the EU-14, collaborating to a large extent among themselves such as Germany, Spain, the Netherlands, France and Denmark. It also confirms that the UK was a central country in terms of the number of its collaborations, having strong links, particularly to Spain, Germany and Denmark.

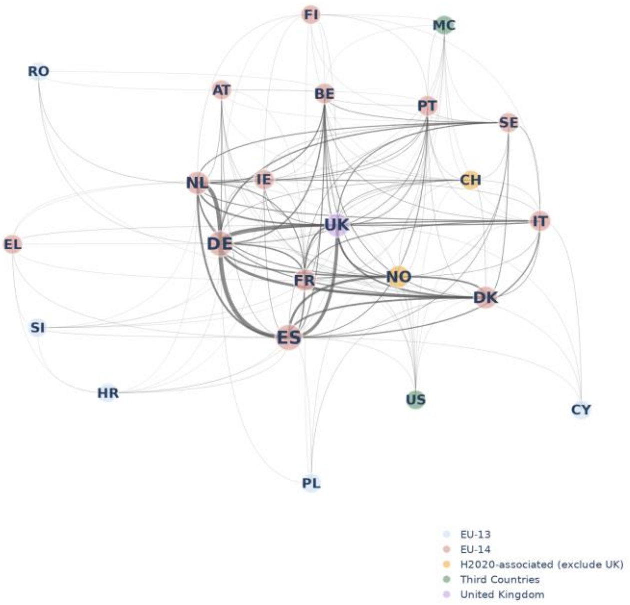

Figure 232 Network of participating countries (of supported organisations) in projects in the Case Study Offshore Wind.

Source: eCorda, own calculation

6.3.4.4. European Partnerships relating to Offshore Wind

In addition to the Horizon 2020 project portfolio and its related calls, two ERA-NET CoFunds relating to offshore wind have been funded, namely DemoWind and DemoWind2. These were funded as part of the H2020 work programme 2014-2015 under the topic LCE 18 – 2014: Supporting Joint Actions on demonstration and validation of innovative energy solutions.

The aim of the two ERA-NETs was to deliver cost reduction in offshore wind by enabling demonstration opportunities that would bring offshore wind technologies to maturity (up to TRL 6-7) through exchanging knowledge and collaboration cross-country. Accelerating the time to market relevant technologies would contribute to cost reduction. They aimed to do so through the coordination of two joint offshore wind technology demonstration calls coordinated by the UK Department for Business Energy and Industrial Strategy.

DemoWind partners were Belgium, Denmark, the Netherlands, Portugal, Spain, and the United Kingdom. 6 collaborative projects were funded through DemoWind between 2015-2020 for a total EU contribution of 7.8 m Euros and a total project cost of 23.6 m Euros.

DemoWind 2 was launched in 2016, and it had 7 partner countries: Belgium, Denmark, the Netherlands, Norway, Spain, Taiwan and the United Kingdom. 5 projects were funded between 2016-2020, with an EU contribution of 3.5m Euros for a total project cost of 10.5m Euros.

Considering the EU contributions to these ERA-NETS, in addition to the contribution to the projects described above (309m Euros), the total EU contribution to offshore wind-related actions has been 320.3m Euros.

6.3.5. Results of the Horizon 2020 funding activities: pathways to impact

6.3.5.1. Technology & Innovation Pathway

Projects funded under Horizon 2020 in the area of offshore wind had a strong emphasis on technological and innovation aspects relevant to the commercialisation of solutions by the private sector. The high relevance of this area to the private sector is confirmed by the high share of funding allocated to private organisations in this area compared with the average for other energy areas under Societal Challenge 3 Energy (SC3). The portfolio was also largely composed of Innovation Actions (IAs), indicating a high degree of application orientation.

Projects addressed the overall priorities of the European Commission in the area of offshore wind, namely cost reduction of Offshore Wind energy and the development of floating offshore wind solutions to be deployed in waters deeper than 50m. Specifically, they targeted these priorities through the development of new or enhanced designs for components, new systems for monitoring, servicing and operating wind farms and demonstration projects.

Many projects focused on the development of components for floating offshore wind, such as new designs for substructures targeting a reduction in the construction and installation costs (for ex., a design for self-floating concrete foundations). Other projects aimed at increasing the reliability of operating wind farms through the development of new systems for monitoring operations and identifying component failure early. For example, one project demonstrated a technology allowing real-time cable monitoring in a relevant environment achieving TRL 6.

Increased efficiency of operating wind farms was another objective targeted by projects, for example, through solutions decreasing the weight of turbines for the same power output, reducing the drag of blades and improving control systems. In the area of maintenance, a project developed a design for a new windfarm service vessel that delivers improved safety for the crew and industrial personnel and lower CO2 emissions. Increased efficiency and decreased costs were also sought through funding a project in meshed offshore networks. Electricity networks play a crucial role in the integration and the price of offshore wind energy, and in meshed offshore networks, there is not only a direct connection from the wind farm to shore but also between wind farms allowing additional functionalities and cheaper and more secure transmission. In particular, two technologies enabling meshed offshore grids were proven to operate safely at the required functionality at TRL 7/8: HVDC (high voltage direct current circuit breakers) and GIS (direct current gas insulated switchgear).

Finally, projects also investigated the potential for implementing multi-functional platforms that enable more efficient use of the sea space, with one project developing a prototype for a multi-functional aquaculture platform. Amongst projects still ongoing, there is also a demonstration of a 12MW wind turbine.

6.3.5.2. Knowledge & Capacity Building Pathway

The projects analysed produced new knowledge on various facets of the operation of offshore wind farms, such as knowledge on ways to improve the reliability and the efficiency of installing and operating wind farms. This includes aspects such as knowledge of the challenges of transporting components of wind farms out at sea or the challenges in servicing existing wind farms and practical, actionable solutions to the problems offering more efficient ways to carry out these processes.

One aspect where the projects explored a new area for developments in offshore wind and produced new knowledge was around the feasibility of the concept of multi-functional platforms at sea. Whilst one project was successful at developing a prototype for a multi-functional aquaculture platform, another project that investigated the feasibility of using floating platforms with different functions (housing, renewable energy production, aqua farming, and logistics) and in different combinations between them identified areas of challenges for the implementation of multi-functional platforms. The main challenge relates to a lack of regulations that could be applied to these activities both due to their location out at sea and to the cross-sectoral aspect of such platforms (combining, for example, energy production with aquaculture of seaweed, algae, or fish). Another element that was identified as a challenge for building such platforms is an increased technological, health and environmental risk from operating multiple functions on the same platform, leading to a lower appetite for investing in these solutions.

Knowledge sharing and dissemination were a core part of the projects funded, with research outputs being publicly available through the CORDIS database and projects engaging in communication activities such as presenting at conferences, publishing articles, and creating communication materials (videos, websites, newsletters). The industry was a key target of the knowledge-sharing activities of the portfolio of projects due to the application-oriented nature of the research funded.

Stakeholders interviewed highlighted that an important contribution of Horizon 2020 projects to knowledge and capacity building has been through the upskilling of workers who have been part of projects and move between different organisations and into the industry, contributing to capacity building of the sector to address European policy priorities. Interviews provide evidence of one example of a researcher moving from an electricity transmission operator to a large company active in the Offshore Wind sector.

It was also noted that the wider offshore wind industry is aware of projects funded under the EU Framework Programmes for Research and Innovation and that there are examples of exploitation of research results from projects that have shown to be successful.

"Industry is interested and follows the projects; if they see there are good things coming out, they start to do these things as well, and they really bring the knowledge into practice. We are giving signals to the whole sector. For example, a multi-rotor wind turbine project was funded under FP7 with a different company, but Vestas then built it themselves as a demonstrator during the time of H2020. The projects together are setting the mindset of the people for the longer-term future, and I think we are building the energy system of the future" (EC Representative)

6.3.5.3. Coordination & Collaboration Pathway

Coordination and collaboration between different stakeholders and geographies played a considerable role in the portfolio. There was a high degree of collaboration between industry, universities and research centres active in Offshore Wind innovation, with private organisations receiving a 65% share of the funding under this portfolio. Geographically, there was a high degree of involvement of EU-14 countries in the portfolio (77.5% of the budget), as well as a high degree of collaboration with the United Kingdom and Norway.

Two projects (CSAs) were funded with the aim of increasing coordination and collaboration between different actors in offshore wind, namely the ETIP Wind project and the SET Wind project. The ETIP Wind project sees Wind Europe coordinate the secretariat of the European Technology Innovation Platform on Wind Energy (ETIP Wind), established in 2016 to inform Research & Innovation policy at the European and national levels by identifying common Research & Innovation (R&I) priorities. The platform coordinates a network of experts from varied backgrounds, including research and industry, who provide advice to the European Commission on research priorities in wind energy. Under Horizon 2020, the ETIP Wind secretariat provided support to the activities of the network of experts to ensure that expert input to the European Commission is timely and relevant. The project has also produced a series of strategies and recommendations, such as two reports on a suggested *Strategic Research and Innovation Agenda* in 2016 and 2018 and a *Roadmap* with recommendations for Horizon Europe.

The SET Wind project supported the implementation of the SET-Plan Offshore Wind Implementation Plan under Horizon 2020 by coordinating the activities of the EERA (European Energy Research Alliance) JP Wind and facilitating the implementation of the research and innovation priorities through the cross-border coordination of nationally funded projects. An important output of the coordination activities of the SET Wind project was the development of two Lighthouse Initiatives aimed at addressing two scientific and technical aspects that are crucial for advancing Offshore Wind energy. The proposed Lighthouse Initiatives is a plea to the EU to support R&D on the topics of floating wind and system integration in a coordinated way and recognise the strategic importance of R&I in these two areas.

The projects funded under the Offshore Wind portfolio analysed showed a high degree of collaboration amongst different geographies, and all stakeholders interviewed noted that coordination and collaboration are a specific EU-added value in carrying out international projects. They noted that Horizon 2020 projects acted as an umbrella for different stakeholders to come together and collaborate on specific aspects of R&I in offshore wind in a way that would not have been possible outside of the framework of the programme:

It takes an understanding of common objectives and being able to unite all of those parties around the common goal. It requires a central party like the EC to guide and steer the project so that it fits overall EU energy-related objectives. (Project beneficiary)

Coordination of different parties through an EU-funded project and under the umbrella of a common understanding of EU priorities was said to be particularly important for innovation encompassing system integration and electricity networks. In the example of project Promotion, Horizon 2020 enabled to carry out the project at scale, including a large geographic representation with different parties involved and for several years. This was fundamental for investigating a concept like meshed offshore grids, which was still immature at the project conception stage and, by nature, required a high degree of cross-country collaboration.

Finally, cross-country collaboration in Offshore Wind R&I was also enabled by the ERA-NET Co-funds DemoWind and DemoWind2, which involved the collaboration of 6 and 7 partner countries, respectively and funding a total of 11 demonstration projects with objectives relating to Offshore Wind cost reduction and involving private sector projects partners ranging from large companies to SMEs across the different participating countries.

6.3.5.4. Market & Business Pathway

The market and business pathway to impact emphasises the cost reduction of offshore wind energy, both thanks to its increased market take-up and increased appetite for investment in offshore wind farms resulting from a lower risk of construction and operation.

During the time of Horizon 2020, the offshore wind sector saw a significant decrease in the levelled cost of offshore wind energy. Lower costs of installation and operation of wind farms and the commercialisation of large wind turbines all contributed to a decrease in cost. The first Horizon 2020 projects had targets that were aiming at reducing the cost to less than 120 Euros per MWh by 2025, which in later projects was changed to a target of 90 Euros per MWh to keep up with the fast cost reduction achieved by industry. Nowadays, the standard price for offshore wind energy has reached 60/70 Euros per MWh, showing that offshore wind energy is significantly cheaper than at the start of Horizon 2020.

However, stakeholders noted that the significant cost reduction in offshore wind energy was delivered mostly by industry and at a much faster rate than the contribution of Horizon 2020 projects to this goal. The cost reduction cannot be attributed to Horizon 2020 interventions to a large degree because most projects were still active and being delivered while the sector experienced a drop in the price of offshore wind from 2017. In addition, it was noted that projects funded under the Work Programmes sometimes were working towards outdated cost reduction targets. This was due to a context were the price of offshore wind was significantly dropping year-on-year, whilst the structure of the Work Programmes did not provide the flexibility to quickly adapt to changing targets.

Contributions from the Offshore Wind portfolio of projects to the Market and Business pathway of impact can be seen in the realisation of pilots and demonstrators providing confidence in new technologies and leading to replication or upscaling. For example, project Promotion proved the safety of operating two technologies that enable the operation of meshed offshore grids for the transmission of electricity to shore. Confidence in operating the technologies safely and at the required functionalities has generated interest in the sector and amongst electricity system operators, with Offshore Wind projects in Denmark[134] and the United Kingdom[135] using the concepts and technologies studied in project Promotion:

"In 2016, not many people were talking about meshed offshore grids, and now not only are they talking about it, but countries, transmission system operators, and regulators are planning how to build those grids and making commitments to real-life projects. Promotion developed the knowledge and made it publicly available so that system operators, developers and governments understand that these networks can actually be built technically, and they can be cost efficient compared to the standard approach of direct connections" (Project beneficiary)

6.3.5.5. Policy & Standards Pathway

The policy and standards pathway encompasses achieving impact through the development of better policy and the adaptation of standards and regulations based on the knowledge produced by Horizon 2020 projects in offshore wind. The portfolio produced new knowledge and evidence relating to a more efficient operation and maintenance of wind farms, advancements in floating offshore wind and the operation of large turbines (>10 MW).

Stakeholders interviewed stated that evidence produced by the projects, in particular strategic advice from the ETIP Wind and the SET Wind projects, informed European Commission policy, including the development of Offshore Wind work programmes under Horizon Europe. It was noted that under Horizon 2020 policy makers have been in dialogue with industry, research centres and universities to define critical actions and priorities in Offshore Wind R&I. The priorities identified for future R&I encompass enabling better system integration and connection to the grid, optimizing components such as making substructures lighter, and further developing floating Offshore Wind.

An important contribution to the policy and standards pathway from projects under the offshore wind portfolio is that the evidence that has emerged from the delivery of a varied set of projects in the above-mentioned areas (large-scale wind turbines, floating offshore, O&M) has provided confidence to

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[134] The government of Denmark is planning to establish two large-scale Offshore Wind farm projects (energy islands) in the North Sea and in the Baltic Sea connecting it to several countries: https://ens.dk/en/our-responsibilities/wind-power/energy-islands/denmarks-energy-islands

[135] The UK electricity system operator National Grid is implementing an Offshore Coordination Project investigating how to efficiently link offshore and onshore transmission networks: https://www.nationalgrideso.com/future-energy/projects/offshore-coordination-project

the European Commission in the feasibility of using Offshore Wind as a way to produce energy on a large scale, at an increasingly competitive price and in the feasibility of integrating it into the energy system in an increasingly efficient way. In fact, offshore wind is considered a cornerstone of the EU renewable energy strategy since it is a key technology enabling the EU to achieve its renewable energy targets and carbon neutrality targets by 2050. In this respect, evidence emerging from the projects provides trust in the feasibility and the reliability of the future energy system, the one targeted by the European Commission to achieve its climate goals:

"We thought about how the energy system should look like in 2030 and 2050, and the projects are delivering in that respect and giving trust in that system and the fact it works" (EC representative)

In addition to providing confidence to policy makers about the feasibility and role that offshore wind can play in the energy system, interviews with project beneficiaries also highlighted how the policy and standards pathway encompasses providing confidence to the market about the direction of R&I in offshore wind. In fact, by funding specific areas in offshore wind R&I, the European Commission provides signals to the market about R&I priorities in the sector, and it steers the industry in its investments:

"On floating offshore, the intensity of research would be lower if there were no positive signals from the Commission that floating offshore wind is one of the ways to go. This signals where to point your attention as a company because it gives clarity that the EC and governing bodies see potential there" (Project beneficiary)

6.4. Conclusion

E.Q. 1.1 How relevant has the Framework Programme been in this area, given the stakeholders' needs and considering the scientific, technological and/or socio-economic problems and issues identified at the time of its design and over time?

The Framework Programme interventions in the area of offshore wind have been relevant to the needs identified by stakeholders and the policy priorities identified at the time of its design. Many interventions were funded to lower the cost of offshore wind energy by increasing the efficiency of installation, operations and maintenance. Another area receiving significant attention was the development of new solutions for floating offshore wind.

The relevance of the Framework Programme has been supported by SET Plan bodies (ex., ETIP Wind) producing strategic research agendas on the basis of recommendations from the wind energy expert community. Over the progression of the Framework Programme, innovation in floating offshore wind (including the development of a large 10MW Floating Offshore Wind Turbine) and system integration to deliver electricity onshore were given progressively more importance.

E.Q. 4.1. What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects leading to the achievement of the programme's objective(s) in this area?

The projects analysed as part of this case study delivered an increase in publicly available knowledge and evidence on a variety of innovations in offshore wind. Out of 32 projects, 21 are closed. From a technical point of view, these delivered new designs for offshore wind substructures, new systems for monitoring operations and identifying component failure, or servicing wind farms. Progress was made on meshed offshore networks, and two enabling technologies were proven to operate safely at the required functionality. Amongst projects still ongoing, there is also a demonstration of a 12MW wind turbine.

Another key result of the projects was the upskilling and training of people who move between organisations and into the industry, alongside the uptake of concepts and designs studied under Horizon 2020 projects by industry.

E.Q 4.2. Which internal or external factors have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact?

Among the factors that influenced project progress positively, we find collaboration and cooperation. Collaboration of various parties within projects (such as companies, research institutes, interest groups, etc.) and across a representative geographic base enabled project success through the inclusion of diverse viewpoints, which strengthened the offering developed. It also enabled the dissemination of results to relevant audiences across multiple countries, which generated interest in the project and took up results after the project ended.

Among the factors hindering progress, stakeholders noted a certain inflexibility of the Framework Programme in the face of a rapidly changing offshore wind sector. It was mentioned that project objectives relating to cost reduction would become outdated fast in a context where the price of offshore wind was significantly dropping year-on-year and that funding was provided to projects working to outdated cost reduction objectives compared to market prices.

E.Q 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The Horizon 2020 Framework Programme work programmes have established a portfolio of interventions in the offshore wind field which provides important foundations for progress towards the European Union energy policy priorities under the European Green Deal and the Sustainable Development Goals (SDGs), namely SDG7 Affordable & Clean Energy and SDG13 Climate Action. Significant progress was made in offshore wind during the time of Horizon 2020, and offshore wind technology is now considered a mature technology.

Further progress in the two priority areas identified by offshore wind stakeholders in the two Lighthouse projects will be key, namely in floating offshore wind and system integration. Further R&D to reduce the cost of the balance of the plant (electrical kit substations, cables) will also be key for an overall reduction of the levelled cost of offshore wind energy and its wider market take-up.

The Paris agreement was a moment when the EU realised that renewables were no longer a “nice to have”, and there was an urgency to accelerate climate action. Having operational offshore wind farms in the North Sea

EQ 4.5. To what extent has international cooperation and, more specifically, association of third countries to the EU Framework Programme made a difference in achieving the environment related objectives of the Framework Programme?

International cooperation played a considerable role in the portfolio, with high project participation from the United Kingdom and Norway due to their activity in the offshore wind sector in the North Sea. However, within the EU, the most active countries belonged to the EU-14 (Germany, Spain, the Netherlands, France and Denmark).

EQ 5.1. What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

The EU added value of the Framework Programme in the area of offshore wind seems to have been high for two aspects: a) cooperation and collaboration under common objectives b) supporting the diffusion of offshore wind in countries that were not traditionally active in this sector, making it a “whole European story”.

Regarding cooperation and collaboration, Horizon 2020 allowed projects to be carried out at the scale required across different geographies and stakeholders for several years. International collaboration was key for the delivery of certain projects of the offshore wind portfolio, for example, a project working on offshore meshed grids, which by its nature requires cross-border collaboration. The Framework Programme has provided an umbrella under which to coordinate research efforts towards common objectives, and financial contribution was said to be a value-added to mobilise parties across countries, whilst other regional or international cooperation initiatives are more difficult because they do not provide funding for delivering R&I (for ex. under the International Energy Agency or the European Energy Research Alliance), or they focus principally on aligning political priorities (for ex. the North Seas Energy Cooperation).

Horizon 2020 played an important role in supporting the development of an offshore wind sector, in particular floating offshore in countries bordering the Atlantic Ocean and the Mediterranean Sea, also due to a requirement for projects to collaborate across an extensive geographical coverage.

6.5. Annexes

6.5.1. Key metadata of the case study no. 6 'Offshore Wind'

Table 61. Summary of Case Study n. 6 'Offshore Wind'.

Case no. 6	**Offshore Wind energy**
Evaluation Question addressed	EQ 1.1; 4.1; 4.2.; 4.4.; 4.5.; 5.1.
Area	Societal Challenge 3, Energy
Programme parts	WP 2014/2015 (Secure, clean and efficient energy) WP 2016/2017 (Secure, clean and efficient energy) WP 2016/2017 (Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy) WP 2018/2020 (Secure, clean and efficient energy) WP 2018/2020 (Cross-Cutting Activities Area 2: Clean, affordable and secure energy)
Scope	18 Horizon 2020 calls Time horizon covered: 2014 – 2020. Number and type of instruments analyzed: 8 RIAs, 7 IAs, 1CSA, 1 ERA-NET and 2 SME Instruments Number of projects analysed: 32
Key data sources	H2020 Work Programs & relevant call text Project data from CORDIS & CORDA 6 interviews (3 Experts, 1 Policy Officer, 2 Project Beneficiaries) Strategic Policy Documents (Set Plan Strategic Plan, European Wind Initiative, Set Plan Implementation Plan for Offshore Wind)
Links with partnerships	ERA-NET Demo Wind and ERA-NET Demo Wind 2
Relevant policies	European SET Plan European Green Deal Fit for 55 Energy Union Sustainable Development Goals 7 (Affordable & Clean Energy) and 13 (Climate Action) Paris Agreement Renewable Energy Strategy

Table 62. Project information.

Project Acronym	Action Type	Project Call ID	EC Net Contribution
CL-Windcon	RIA	H2020-LCE-2016-RES-CCS-RIA	4,931,423
COREWIND	RIA	H2020-LC-SC3-2018-RES-TwoStages	5,031,859
DEMOGRAVI3	IA	H2020-LCE-2015-2	19,037,466
EcoSwing	IA	H2020-LCE-2014-2	10,591,734
ELICAN	IA	H2020-LCE-2015-2	11,181,987
ELISA	SME-2	H2020-SMEINST-2-2014	2,497,863
EU-SCORES	IA	H2020-LC-GD-2020-1	34,831,484
FLAGSHIP	IA	H2020-LC-SC3-2020-RES-IA-CSA	24,920,290
FLOATECH	RIA	H2020-LC-SC3-2020-RES-RIA	4,096,355
FloatMastBlue	SME-2	H2020-SMEINST-2-2016-2017	2,048,568
FLOTANT	RIA	H2020-LC-SC3-2018-RES-TwoStages	4,944,958
GreenHyScale	IA	H2020-LC-GD-2020-1	30,000,000
HIPERWIND	RIA	H2020-LC-SC3-2020-RES-RIA	3,999,639
i4Offshore	IA	H2020-LC-SC3-2018-RES-SingleStage	19,877,916
LIFES 50plus	RIA	H2020-LCE-2014-1	7,274,838
MooringSense	RIA	H2020-LC-SC3-2019-RES-TwoStages	4,197,620
NEXUS	IA	H2020-BG-2017-1	3,337,099
OYSTER	JTI-FCH2-RIA	H2020-JTI-FCH-2020-1	4,999,843
PivotBuoy	RIA	H2020-LC-SC3-2018-RES-TwoStages	3,960,065
POSEIDON	SME-2	H2020-SMEINST-2-2014	1,144,150
PROMOTION	IA	H2020-LCE-2015-3	34,480,932
ReaLCoE	IA	H2020-LCE-2017-RES-IA	24,838,258
Riblet4Wind	IA	H2020-LCE-2014-2	3,307,172
ROMEO	IA	H2020-LCE-2016-RES-IA	9,999,813
SENTRY	SME-2	H2020-SMEINST-2-2016-2017	1,380,871
SETWIND	CSA	H2020-LC-SC3-2018-Joint-Actions-2	998,512
Space at Sea	IA	H2020-BG-2017-1	6,766,793
TELWIND	RIA	H2020-LCE-2015-1-two-stage	3,498,530
The Blue Growth Farm	IA	H2020-BG-2017-1	7,602,873
TotalControl	RIA	H2020-LCE-2016-RES-CCS-RIA	4,876,483
WATEREYE	RIA	H2020-LC-SC3-2019-RES-TwoStages	4,709,369
XROTOR	RIA	H2020-LC-SC3-2020-RES-RIA	3,900,009

6.5.2. Horizon 2020 calls analysed

Table 63. Horizon 2020 calls analysed.

WP 2014/2015 (Secure, clean and efficient energy)	**LCE 1-2014/2015: New knowledge and technologies** **LCE 2-2014/2015: Developing the next generation technologies of renewable electricity and heating/cooling** **LCE 3-2014/2015: Demonstration of renewable electricity and heating/cooling technologies** **SIE 1 – 2014/2015: Stimulating the innovation potential of SMEs for a low carbon and efficient energy system** **LCE 18 – 2014/2015: Supporting Joint Actions on demonstration and validation of innovative energy solutions**
WP 2016/2017 (Secure, clean and efficient energy)	LCE 7-2016-2017: developing the next generation technologies of renewable electricity and heating/cooling LCE-13-2016: Solutions for reduced maintenance, increased reliability and extended life-time of off-shore wind turbines/farms LCE-14-2017: Demonstration of large >10MW wind turbine SMEInst-2016-2017: Stimulating the innovation potential of SMEs for a low carbon and efficient energy system
WP 2016/2017 (Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy)	BG-01-2016: Large-scale algae biomass integrated biorefineries
WP 2018/2020 (Secure, clean and efficient energy)	LC-SC3-RES-1-2019-2020: Developing the next generation of renewable energy technologies LC-SC3-RES-11-2018: Developing solutions to reduce the cost and increase performance of renewable technologies LC-SC3-RES-13-2018: Demonstrate solutions that significantly reduce the cost of renewable power generation LC-SC3-RES-14-2019 - Optimising manufacturing and system operation LC-SC3-RES-19-2020: Demonstration of innovative technologies for floating wind farms LC-SC3-RES-31-2020: Offshore wind basic science and balance of plant LC-SC3-JA-2-2018-2019: Support to the realisation of the Implementation Plans of the SET Plan
WP 2018/2020 (Cross-Cutting Activities – Area 2: Clean, affordable and secure energy)	LC-GD-2-1-2020: Innovative land-based and offshore renewable energy technologies and their integration into the energy system LC-GD-2-2-2020 - Develop and demonstrate a 100 MW electrolyser upscaling the link between renewables and commercial/industrial applications

7. Case study 7: Biofuels

7.1. Summary

The case study identifies and analyses relevant actions related to biofuels in Horizon 2020 and respective partnerships (ERA-NET Co-fund BESTF3 Bioenergy Sustaining the Future). The thematic scope of the case study comprises the following biofuel technology pathways: 1) BioMethan & bioLPG, 2) alcohols, ethers and esters 3) synthetic paraffinic fuels. Within this thematic scope, the case study analysed 9 RIAs, 5 IAs, 3 CSAs, 2 SME Instruments, and 4 BESTF3 ERA-NET calls totalling 72 projects.

Whilst the interventions in the Biofuels area were able to contribute to European Union policy priorities, there is no silver bullet biofuel technology that can by itself make big advancements towards a green transition. External factors such as unstable political market and framework conditions, negative public perception of biofuels or the absence of a commonly accepted methodology for biofuel assessment are stifling further market uptake and integration and underscore the need to direct attention to these enabling factors in which biofuel technologies are embedded. However, the framework program was able to support biofuel research and development in several ways. For example, the creation and institutionalisation of expert networks, the internationalisation of research teams and the establishment and solidification of new research streams would have been very difficult to achieve with national R&I funding alone and enabled biofuels to progress in Europe and to make steps towards reaching the objectives the H2020 framework program.

7.2. Introduction and Overview

7.2.1. Objectives

The case study focuses on the effectiveness of H2020 in developing next-generation biofuels and introducing them into the market, including transport sectors (road, aviation and shipping). The thematic scope of the case study comprises the following biofuel technology pathways: 1) BioMethan & bioLPG, 2) alcohols, ethers and esters 3) synthetic paraffinic fuels.

Activities focus on the diversification of renewable fuel production through novel feed stock and conversion routes and on the market roll-out of liquid biofuels. The case study also includes international cooperation activities pursued under the framework programme related to biofuels. To this end, the case study identifies relevant activities related to biofuels within Horizon 2020, analyses their implementation and how the results and outcomes contribute to the goals of Horizon 2020 as well as overarching European policy priorities.

7.2.2. Methodology and case study structure

The case study analysis included 19 Horizon 2020 calls and the ERA-NET Co-fund BESTF3 Bioenergy Sustaining the Future. The time horizon investigated covered 2014 – 2020. The number and type of instruments analysed are 9 RIAs, 5 IAs, 3 CSAs, 2 SME Instruments and 4 BESTF3 ERA-NET calls. An overview is provided in the Annex of this case study.

The case study analysis commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to Biofuels (e.g., SET Implementation Plan Action 8, STRIA roadmap for low-emission alternative energy for transport (ALT); EERA Bioenergy Strategic Research and Innovation Agenda; ETIP Bioenergy Strategic Research and Innovation Agenda). We then identified relevant project actions in Horizon 2020 based on a key-word search of topics in the work programs. The focus was put on SC3, but also other programme parts were screened. The first project selection was based on a call topic search and subsequently narrowed down and validated. For the identified projects, relevant data (as available from Corda data) were compiled and analyzed, including budget, number of project participants, geographic origin and types of beneficiaries, project type, project results and outputs (publications, patents). For the most relevant actions, this was complemented by further information from additional sources like project websites.

In addition to the project data analysis, we performed 5 interviews with relevant stakeholders. These were representatives of the European Commission in charge of the topic (DG RTD), thematic experts involved in European strategic processes (i.e., experts involved in Alternative fuels STRIA roadmap) and project coordinators of relevant projects. Interviews followed a semi-structured, exploratory approach. The design of the interview guidelines was based on the evaluation questions and the specific interview partner.

For data analysis, we triangulated all data in relation to the evaluation questions (EQ 4.2.; EQ 4.3; EQ 4.4.; EQ 4.5.; EQ 5.1.).

7.3. Synthesis of evidence

7.3.1. Biofuels and a green transition

The EU set itself ambitious targets for the use of more sustainable energy in different sectors to reduce GHG emissions and reduce fossil fuel dependencies (for details of these targets and strategies, see section 2.2.). Of particular concern for reaching these targets is the transport sector because it is one of the largest energy consumers in the European Union with a high dependency on fossil fuels. In 2016, the EU 28 transport sector, excluding international shipping, consumed 367.3 Million tons of oil equivalent (Mtoe), which accounted for 33.3 % of total energy consumption. While the total GHG emissions have decreased in the EU, the share of transportation GHG emissions of total emissions increased significantly during the last two decades, out of which road transport was the biggest contributor[136].

Whilst it is unlikely that biofuels will completely replace fossil fuels in all transport modes, they represent a viable alternative that can reduce the demand for oil-based fuels and, thus, GHG

[136] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Greenhouse_gas_emission_statistics_-_carbon_footprints

emissions.[137] Nearly all the demand for biofuels in the EU is currently coming from the road transport sector in which ethanol, biodiesel (Fatty Acid Methyl Esters) and renewable diesel (Hydrotreated vegetable oil and hydro-processed esters and fatty acids) are mainly used[138].

Policies such as the renewable energy directive (RED I and RED II) and the fuel quality directive (FQD) (see section 2.2 for more details) have boosted the demand for biofuels so that in 2019, biofuel consumption in the EU reached 17.8 Mtoe. In fact, biofuel consumption has shown a steady increase in the EU over the years (Figure 1). [139]

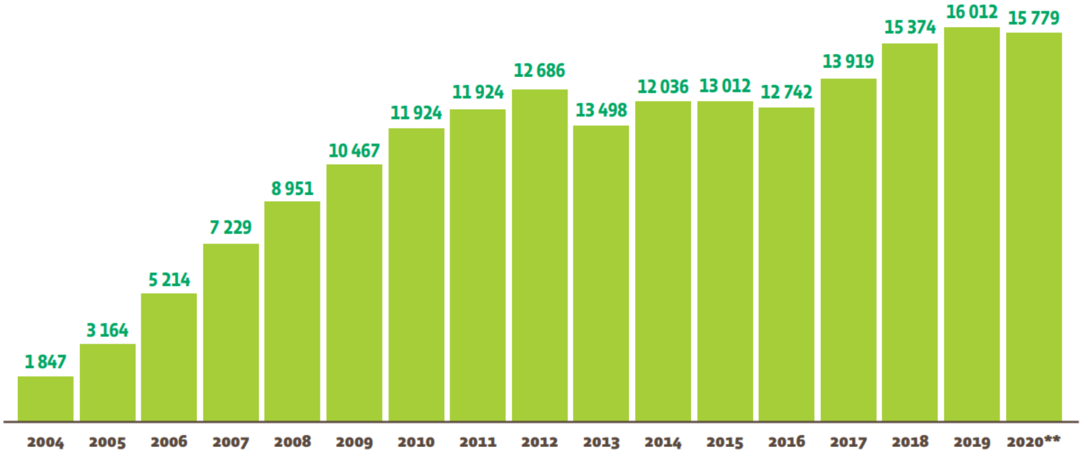

Figure 233. European Union (EU-27) biofuels consumption trends (in ktoe).[140]

The breakdown of biofuel type in Figure 2 shows that mainly ethanol and biodiesel are used in transport. It is important to note that Ethanol and biodiesel are mainly produced from energy crops that are in competition with food or feed crops (e.g. corn, sugar cane, wheat, and sugar beet). Biodiesel and renewable diesel are derived from vegetable oils such as rapeseed, palm oil or soy which is often supplemented by waste oils such as cooking oils. This has important implications from a sustainability perspective because these feedstocks can lead to indirect land use changes, and are in competition with food and feed crops which limits their sustainability benefits as well as their greenhouse gas reduction potential.

7.3.2. Strategic policy priorities related to biofuels and a green transition

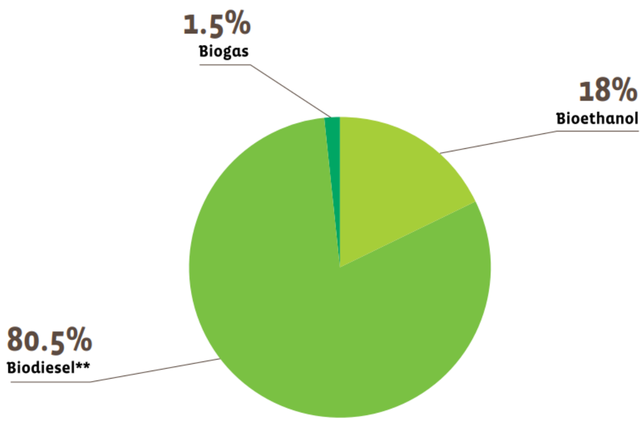

Figure 234. EU Biofuel consumption breakdown for transport.

The **European Green Deal** included a commitment to increase the EU's GHG reduction target for 2030 to at least 50%, relative to 1990 levels, and to target net zero emissions by 2050. This target will require a 90% reduction in transport emissions by 2050. The 2030 **Climate Target Plan** builds on this

[137] https://trimis.ec.europa.eu/sites/default/files/2021-03/alternative_fuels_stria_april2020_final_version_newcover_0.pdf
[138] https://www.oecd-ilibrary.org/sites/19428846-en/index.html?itemId=/content/publication/19428846-en
[139] https://www.eurobserv-er.org/biofuels-barometer-2020/
[140] Source: https://www.eurobserv-er.org/biofuels-barometer-2020/

by increasing the target to a 55% reduction in greenhouse gas emissions (relative to 1990) by 2030 as a step on a path to climate neutrality by 2050. These targets point to the need to ramp up the production and deployment of sustainable alternative transport fuels such as biofuels. Consequentially, the energy and climate policy of the EU places a great emphasis on the deployment of sustainable advanced biofuels. By 2030, the EU aims to increase the share of renewable energy in transport to at least 14%, including a minimum share of 3.5% of advanced biofuels. Most notably, this share shall be increased by using replacement fuels from lignocellulosic energy crops, residues, and power to gas/liquid that does not compete with food or feed crops for agricultural land.

A few strategic policies at the EU level are directly relevant to achieving these goals. For example, the

European Strategic Energy Technology Plan (SET-Plan) Action 8, called “Bioenergy and Renewable Fuels for Sustainable Transport”, describes the research and innovation activities required for achieving the targets adopted in the SET Plan declaration of intent. The SET Plan implementation plan focuses on three areas for biofuel R&I: 1) improve performance (yield and efficiency) of production, 2) reduce GHG emissions along the value chain and 3) reduce costs.

To further the implementation of the SET plan Action 8 implementation plan, the ETIP Bioenergy was established (European Technology and Innovation Platform), and its objectives were enshrined in the **ETIP Bioenergy Strategic Research and Innovation Agenda.** ETIP Bioenergy combines the efforts of the European Biofuels Technology Platform (EBTP, which started in 2006) and the European Industrial Initiative Bioenergy (EIBI, which started in 2010). It brings together EU countries, industry, and researchers in key areas and promotes the market uptake of energy technologies by pooling funding, skills, and research facilities.

The current **Renewable Energy Directive (RED II)** came into effect in December 2018 as part of the **Clean Energy for all Europeans Package.** The directive set the overarching policy framework for the promotion and use of biofuels in the EU. RED II also provides a specific target for the use of advanced biofuels of 0.2% in 2022 for each Member State, followed by at leas 1% in 2025 and 3.5% in 2030. The directive also reinforcers the sustainability criteria that are relevant for biofuels to prevent negative indirect and direct consequences such as indirect land use change (i.e. the extension of agricultural land into non-crop land, possibly including areas with high carbon stock, such as forests, wetlands and peatlands).

Similar to the RED II, the **Fuel Quality Directive (FQD)** requires that biofuels should meet certain sustainability criteria (it also applies to biofuels for heat and power rather than just transport use). The criteria cover the greenhouse gas emissions savings from using the fuels (e.g. minimum of 60% GHG savings compared to fossil fuel to be eligible for support) and the types of land that may be converted for biofuels production (i.e. feedstocks for biofuels cannot be sourced from land with high biodiversity or high carbon stock). The directive also poses requirements and conditions on European feedstock production on cross-compliance with agricultural sustainability rules.

Furthermore, the **Indirection Land Use Change (ILUC) Directive** capped the use of 1st generation biofuels (i.e. biofuels produced from starch, oil or sugar crops in the EU). The directive establishes a requirement for member states to assess ILUC emissions when accounting for greenhouse gas emissions of biofuels, and it includes provisions for limiting the use of biofuels from food-crops.

7.3.3. Horizon 2020 programming related to biofuels

7.3.3.1. Horizon 2020 Work Programmes related to Bio Fuels

Biofuel objectives have been present in three biannual work programs of Horizon 2020 in different program parts, most notably in the ones related to SC3 Energy. The following sections summarise the priorities of each work program:

The **work programme 2014-2015** set out the goals under the title “Competitive Low Carbon Energy”, which were to make the EU energy system clean, secure, and efficient while ensuring EU industrial leadership in low-carbon energy technologies. Amongst other renewable energy technologies, Biofuels are one an important part of achieving this goal and the work program emphasizes their potential impact in terms of decarbonising the transport sector. In particular, it emphasizes Biofuels importance in transport sub-sectors such as aviation, heavy duty road transport and maritime transport which have a lower potential for electrification and thus a greater reliance on combustible fuels. The work program further focuses on the development of advanced biofuels and the commercialisation of biofuels based on lignocellulose and other non-food feedstock.

The **work programme 2016-2017** reinforced the goals set out by WP 2014-2015 while emphasising the continued role that the SET-Plan plays. The programme stated the essential role of renewable energy technologies but also moved the energy system and other constituting elements to the fore. In this regard, the importance of transnational connections between member states energy systems is emphasized, but also the role of active consumers in achieving the goals of the program. This systemic perspective is also reflected in the emphasis on integrated approaches for renewable energy technologies. The WP emphasises the importance of diversifying biofuel production while using domestic sources for feedstock in order to secure supply. Furthermore, it specifies that support priority will be given to biofuel technologies with the highest maturity levels and thus cost competitiveness while simultaneously ensuring appropriate levels of support for new and emerging technologies. Biofuels for the aviation sector as well as international cooperation with Brazil on advanced lignocellulosic biofuels, are also of importance in this WP.

The **work programme 2018-2020** links SC3 to the focus area "building a low-carbon, climate-resilient future," which underpins the goals of the 2016 Paris Agreement, as well as the "Clean energy for all Europeans" package (including the Renewable Energy Directive) and the SET-Plan priorities (most notably action 1,2 and 8 which relates to biofuels). The WP highlight four lines of intervention. First, the development of breakthrough technologies. Second, the implementation of renewable energy solutions (electricity and heating) at the consumer scale. Third, the implementation of renewable energy solutions at the energy system level. Fourth, the development of renewable fuels for transport aiming for feedstock and process improvements and supporting road, aviation and shipping sectors in particular. Furthermore, international cooperation with Japan and Canada is emphasized in this WP.

Points of **commonality between the work programmes** are a focus on increased market uptake of Biofuels and a concerted push towards reaching cost-competitiveness of Biofuels as affordable and resource-efficient solutions that can decarbonise the transport sector and reduce the GHG emissions of the energy sector while improving supply security and reducing dependencies on fossil fuels from politically volatile countries. Additional commonalities are a focus on the diversification of biofuels with a focus on advanced biofuels, which reduce the reliance on feedstock that can lead to land use conflicts or indirect land use changes typically associated with first-generation biofuels. Of note is also the emphasis on industry involvement and industrial scale demonstrations as well as an emphasis on the use of biofuels in the transport sector (and to a lesser extent for power generation and heating sectors). In particular, the WPs display a focus on aviation and shipping (and to a lesser extent on the road), which is justified by the limited potential of these transport sub-sectors for electrification and the improvement of second-generation biofuels technologies in terms of energy content and combustion properties. Over time, the work programs started to place greater importance on the synergies with other sectors and the integration of biofuels in the overall energy system.

7.3.3.2. Summary of policy priorities

The analysis of the Work Programmes and the projects revealed distinct pathways to impact that connect the activities carried out within the work programme with identifiable effects (outcomes). Based upon the Work Programme analysis, Figure 251 provides an overview of 5 pathways to impact identified in the analysis of the Biofuels case.

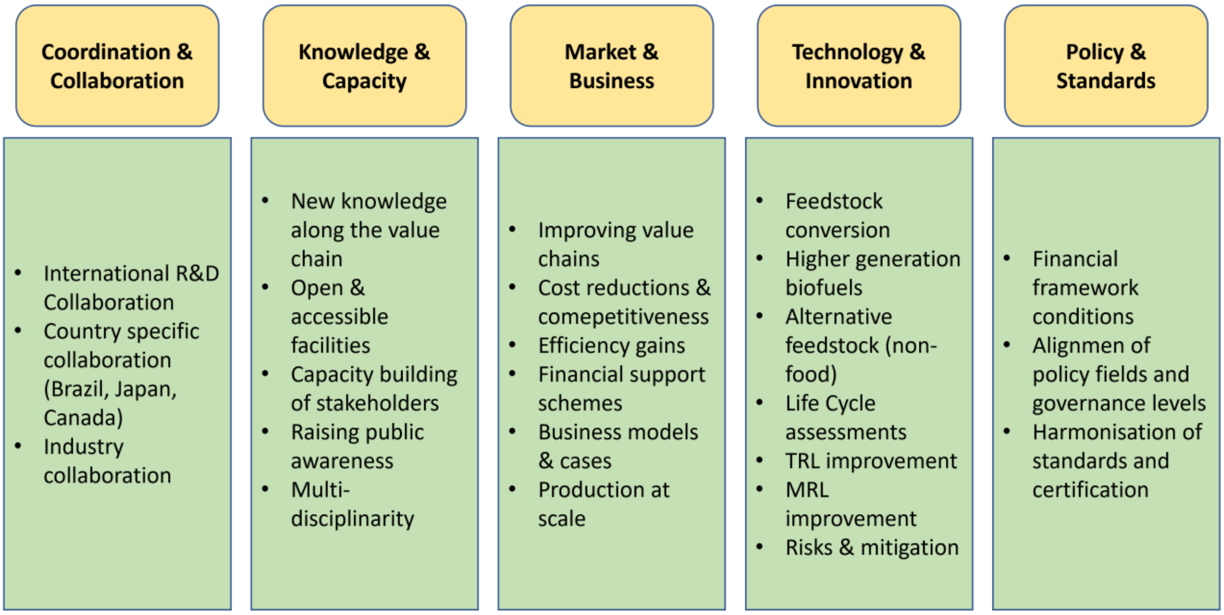

Figure 251. Biofuels case pathways to impact and their particularities.

7.3.3.3. Coordination and Collaboration Pathway

International collaboration for knowledge and experience exchange in mutually beneficial strategic areas was prevalent in the work programs and in the portfolio analysed. This involved cooperation between key researchers (from university and non-university research organisations such as RTOs) and industry partners, including SMEs. The reason for collaboration was often in relation to the development of new technology solutions across the entire value chain (see Technology & Innovation Pathway) and with different, often country-specific, feedstocks. In this regard, the collaboration of R&D stakeholders between EU member states and three third countries stood out in this pathway:

First, synergies between **Brazil** and European member states were pursued in terms of scientific expertise and resources related to advanced lignocellulosic biofuel production, most notably ethanol. Additionally, international collaboration with **Japan** was pursued, focusing on catalytic technologies and lab-scale components for improving conversion efficiency and cost reduction of bioenergy carriers and non-food-based advanced biofuels. Improvements to conversion technologies and processes and a strengthening of the technology base were in focus in the international collaboration with **Canada.**

Most prominently addressed in the calls was the **industry stakeholder** group, and having an industry partner as part of the consortium was an explicit prerequisite in most of the calls analysed. The quantitative data analysis supports this focus on industry stakeholders and shows their high relative share of EC contribution (see Section 2.4.1 for more detail). The importance of instigating collaboration with this stakeholder group was due to the importance of demonstrating the financial and operational viability of biofuel technology solutions at scale. As such, commercialisation aspects and the demonstration of production quantities at an industrial scale was notable element when industry collaboration was pursued. In this regard, exploitation plans were often seen as a necessity to specify the actions related to the protection, dissemination, and exploitation of the project results.

7.3.3.4. Knowledge and Capacity Building Pathway

The project analysed produced **new knowledge** and practical insights on different facets of biofuels **along their entire value chain,** from feedstock production, feedstock processing, and biofuel transformation to biofuels conversion, distribution and market or end-user aspects. One aspect in relation to this was the need to develop new or advanced existing assessment methodologies for biofuels (e.g. life cycle assessment or well-to-wheel analysis).

Associated with this knowledge generation were targeted dissemination activities of project results for an academic as well as practitioner or industry audience. Besides using traditional channels, knowledge sharing and capacity building was also often enabled by making **test sites, pilot and demonstration facilities, or research infrastructures accessible** to others so that practice-oriented education, training or knowledge exchange is facilitated.

Capacity building was targeted at **the main stakeholder** across the entire value chain of biofuels, from farmers as feedstock and biomass providers to biofuel production stakeholders as well as decision-makers, financial institutions, auditors, and verification bodies.

Increasing public knowledge, **raising public awareness** and improving the perception about biofuels through targeted communication was also an important consideration in this pathway (particularly around advanced biofuels). This focus area can be attributed to the negative image associated with some of the older-generation biofuels produced from food crops and emotional debates about the sustainability of first-generation biofuels.

Whilst many of the projects analysed had a focus on engineering and natural sciences, **multi-disciplinary approaches** were also considered valuable, particularly for addressing the systemic barriers outside of the technological domain which was hindering market penetration and more widespread uptake of biofuels (e.g. policy & regulatory barriers; public awareness & acceptance).

7.3.3.5. Market & Business Pathway

A prominent feature of the market and business pathway was to **improve the economic competitiveness of biofuels along their entire value chain** as well as strengthen supply chains at the European, national or local levels. An avenue for improving the economic competitiveness of biofuels was through **cost reductions** of biofuel production processes to come closer to or match, the production costs of fossil fuels. Such cost reductions were pursued through **efficiency gains** along the value chain of biofuels. Improving efficiency was linked to the use of natural resources and the use of alternative feedstocks or the reduction of the biomass resources used for conversion. Additionally, efficiency gains were pursued by reducing the demand for energy and water in the production process.

Another aspect of this pathway concerns the development of **tailored financing schemes** for attracting private sector investments in innovative as well as more established biofuel technologies. This meant that some projects developed financing schemes to leverage other funding opportunities while undertaking biofuel projects to replicate and upscale project outputs.

Projects funded in the work programs pursued bankable solutions, which required the **development of sound business models and business cases** for new biofuel technologies and products. This was an important aspect in terms of demonstrating the financial viability of large-scale or industrial-scale biofuel production. To this end, pre-commercial testing of biofuel technologies and production **demonstration in large quantities** were important related aspects.

7.3.3.6. Technology and Innovation Pathway

Almost all projects in the portfolio analysed pursued the development of technological solutions at different points in the value chain: from technological improvements in relation to the supply and processing of biomass, the advancement of intermediate carriers as energetically denser, storable and transportable intermediary products and the valorisation of co-products, to the actual use of the produced biofuel in a transport (sub) sector (e.g. aviation).

The pathway placed emphasis on novel solutions for **converting new feedstock** through either chemical, biochemical and thermochemical pathways or a combination of them. This allows for tapping into new feedstock supplies and reducing supply costs. In particular, new **solutions for higher generation non-food/feed biofuels** using fractions or by-products in forestry, agricultural, as well as organic municipal and industrial wastes were pursued therefore improving feedstock supply and diversifying the supply channels. In particular, the use of seaborne aquatic biomass such as macro-algae or fish residues in large quantities was sought. Underpinning this focus was the need to reduce the competition with a feedstock that can lead to land use conflicts typically associated with first-generation biofuels. In this regard, emphasis was placed on **whole-life cycle assessments** of proposed solutions which take health and safety aspects as well as social, environmental and economic impacts into account.

This pathway was also marked by projects that aimed at **improvements to the Technology Readiness Level (TRL)** of biofuel technology solutions. This involved improving TRL levels of a solution either from a low to medium level (TRL 3 or TRL 4) as well as solutions at medium to higher levels (TRL 7 or TRL 8) which points to a balance between basic technology research activities for finding novel solutions as well as more applied research in terms of advancing the deployment of existing solutions and commercial application. In both cases, an improvement by at least one, sometimes by two, TRL levels was pursued. Related to this aspect was a focus on keeping the **MRL (Manufacturing Readiness Level) aligned** with the advances in the TRL levels to ensure the potential for exploitation.

Another important element in this pathway was related to a better understanding and anticipation of risks (whether technological or business-related) and associated risk ownership and opportunities for risk mitigation. Additionally, improving the efficiency of existing solutions and processes by, e.g.

reducing conversion energy losses, improvements to the fuel feedstock quality, and thereby moving towards a more favourable energy balance was a common theme (see also Market & Business Pathway for the logic of efficiency gains & cost competitiveness).

7.3.3.7. Policy and Standards Pathway

The intervention characteristics of the Policy and Standards Pathway targeted the **legal, institutional and political frameworks at the local, national and European levels** and the conditions that these frameworks create for enabling or hindering the widespread use of biofuels. In addressing this ambition, three avenues stood out in the work programs and the projects analysed.

First, policy support specific to the market uptake of biofuels was highlighted and actively pursued. This involved seeking **improvements to the financial framework conditions** at the national, regional and local levels. Policy support and coordination for market uptake were also reflected in linkages with platforms such as ETIP Bioenergy on this topic.

Second, the **alignment between different policy areas and levels of governance** was pursued. This involved horizontal coordination of policy fields that are relevant to biofuels, such as energy policy, agricultural policy, environmental policy, and transport policy. Additionally, vertical harmonisation of governance structures and processes (e.g. national and regional level) was pursued to improve the regulatory framework condition for biofuel production and use.

Third, addressing current market and regulatory barriers and, in particular, the ones associated with the **harmonisation of national standards** and improvements to (voluntary) certification schemes that testify to the sustainability criteria in the production of biofuels at the EU and national level was another focus area.

7.3.4. Project portfolio characteristics

The project portfolio of this case comprised 72 projects from 19 calls across the WPs.

Table 64. Type of organisations in Biofuels case.

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1000)
		Nb	Share (%)	EUR (1000)	Share (%)	
HES	56	156	19%	61,483	17%	394.1
OTH	33	95	12%	18,593	5%	195.7
PRC	69	333	41%	167,305	47%	502.4
PUB	11	16	2%	2,218	1%	138.6
REC	68	221	27%	102,640	29%	464.4
Total (All types)	**72**	**821**	**100%**	**352,238**	**100%**	**429.0**

HES: Higher or Secondary Education Establishments

PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)

REC: Research Organisations

PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)

OTH: Other

Source: eCorda, own calculation.

The sum of EC's net contribution is EUR 352 Mio, of which 47% has been allocated to private for-profit entities, 29% to research organisations, 17% to higher education institutions, 5% to other organisations and 1% to public bodies. Compared to other case studies in the Green Transition Area, the Biofuels portfolio shows a typical share of funding for private for-profit entities (47% is average in all Green Transition areas) and a slightly lower share of funding for Higher or Secondary Education Institutions (17% in the biofuels case compared to 19% average in all Green Transition areas) but a slightly higher share for Research Organisations (29% in the biofuels cases compared to 24% average in all Green Transition areas). Notable is also a low share of funding for public bodies (1% in the Biofuels portfolio compared to 5% in all Green Transition Areas). Overall, the partner composition of the portfolio can be considered typical, given the focus on technology development and the commercialisation of biofuel solutions across their entire value chain.

Table 65. Type of action/instruments in Biofuels case.

Action/instrument	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)
SME-2	2	3	0.4%	2,824.2	0.8%	941.4
RIA	42	503	61.3%	194,965.7	55.4%	387.6
IA	9	97	11.8%	117,711.8	33.4%	1,213.5
CSA	19	218	26.6%	36,736.7	10.4%	168.5
All types	**72**	**821**	**100.0%**	**352,238.4**	**100.0%**	**429.0**

Source: eCorda, own calculation.

With a 55% share of funding allocated to Research and Innovation Actions (RIA), the Biofuels portfolio is characterised by a high degree of research orientation. Similarly, with 10.4%, the Biofuels portfolio shows a higher share of Coordination and Support Actions (CSA) compared with the aggregated Green Transition project portfolio, in which the share of RIAs is at 41.1 % and the share of CSA at 7.4% of allocated funding. Notable is a lower share of Innovation Actions (IA) in the biofuels portfolio, which is higher on average across all Green Transition Areas (33% in the biofuels portfolio compared to 47% on average in all Green Transition areas).

Within the portfolio of instruments, specific patterns of participation of actor types occur. IAs are more densely populated with private companies, whereas RIAs have a considerable higher share of Higher Education Institutions (HES) and Research Organisations (REC). Public Authorities are completely missing in IAs and relatively low in RIAs. Almost all Public sector organisations participated in CSAs.

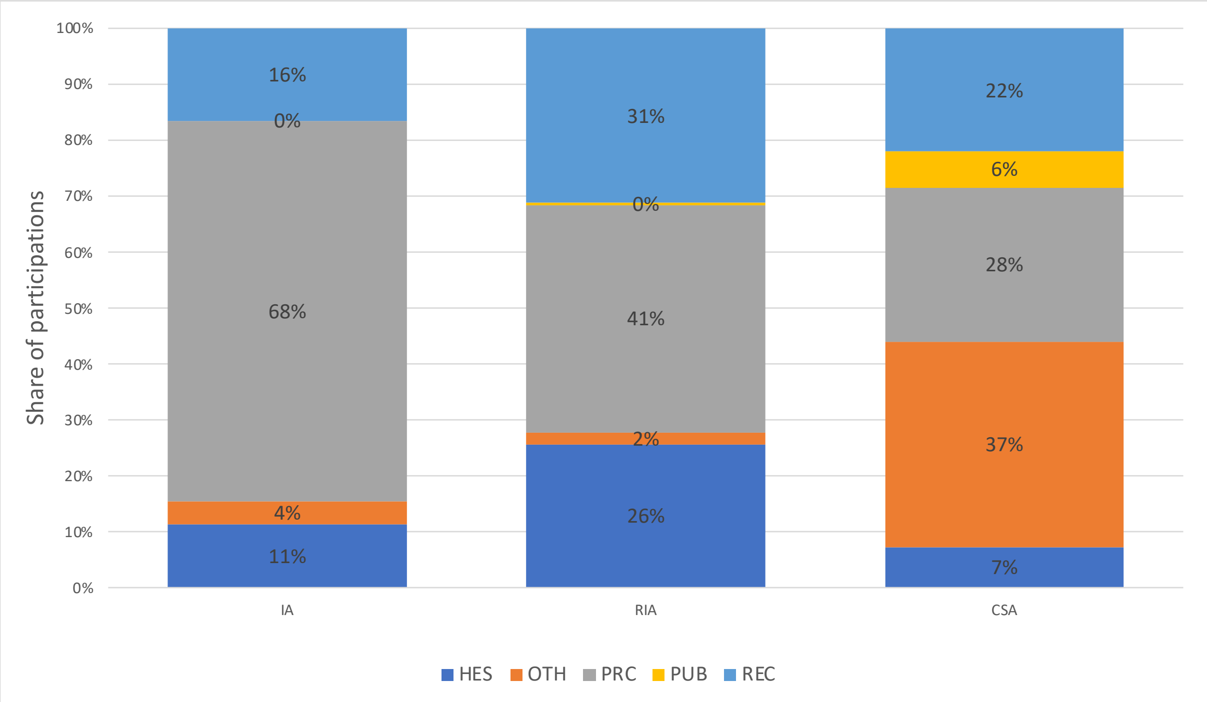

Figure 252. Share (%) of participations by type of action/instrument.

Source: eCorda, own calculation.

Table 66. Group of participating countries of the Biofuels case study.

Group of country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Number of countries
H2020-EU27	72	685	83,4%	307 630	87,3%	449,1	25
EU-14	*72*	*624*	*76,0%*	*296 994*	*84,3%*	*476,0*	*14*
EU-13	*29*	*61*	*7,4%*	*10 636*	*3,0%*	*174,4*	*11*
H2020-associated (exclude UK)	33	52	6,3%	16 105	4,6%	309,7	8
United Kingdom	32	49	6,0%	22 972	6,5%	468,8	1
Third Countries	12	35	4,3%	5 532	1,6%	158,1	15
All-countries	**72**	**821**	**100,0%**	**352 238**	**100,0%**	**429,0**	**49**

Source: eCorda, own calculation.

Geographically, the eCorda statistics show that Horizon 2020 opened up the participation of associated countries and third countries. Associated countries (excluding the UK) have participated in

33 out of 72 projects, and third countries in 12 out of 72 projects. However, the total budget for this group represents only 6.2% of all EU contributions. The largest gap in terms of participation in relation to EC contribution is observed for the EU-13 countries, which participated in 29 projects but received only 3 % of the total budget. This is, however, at an equal level with all Horizon 2020 Green Transition projects across all areas. A low participation rate of EU-13 indicates a high level of exclusiveness that might be detrimental to utilising the full transformation potential of Biofuels across Europe.

In terms of specific country participation, Germany, the Netherlands, and France stand out with the highest share of EC contribution in total funding (16% for Germany, 16% for the Netherlands, 12% for France). Germany, however, also shows the highest number of projects (52), the highest number of participants (117) and thus also the highest absolute EC contribution (57 Million €).

Table 67. Top participating countries in Biofuels case study.

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part.	Order
		Nb	Share (%)	EUR (1,000)	Share (%)	(EUR 1,000)	
Germany	52	117	14,3%	56 971	16%	486,9	1
Netherlands	37	85	10,4%	54 648	16%	642,9	2
Spain	36	71	8,6%	21 967	6%	309,4	3
Italy	35	81	9,9%	23 689	7%	292,5	4
United Kingdom	32	49	6,0%	22 972	7%	468,8	5
Belgium	29	44	5,4%	30 136	9%	684,9	6
France	27	62	7,6%	43 778	12%	706,1	7
Austria	22	30	3,7%	11 021	3%	367,4	8
Finland	21	34	4,1%	16 151	5%	475,0	9
Sweden	20	33	4,0%	17 314	5%	524,7	10
Greece	18	31	3,8%	9 140	3%	294,8	11
Denmark	13	23	2,8%	9 494	3%	412,8	12
Switzerland	13	15	1,8%	4 067	1%	271,2	13
Norway	12	16	1,9%	8 350	2%	521,9	14
Croatia	8	10	1,2%	1 137	0%	113,7	15

Source: eCorda, own calculation.

The network analysis based on the number of collaborations among organisations from each pair of countries in the projects included in this case study confirms that the Biofuels project portfolio shows a high collaboration intensity among a number of core countries, predominantly from the EU-14.

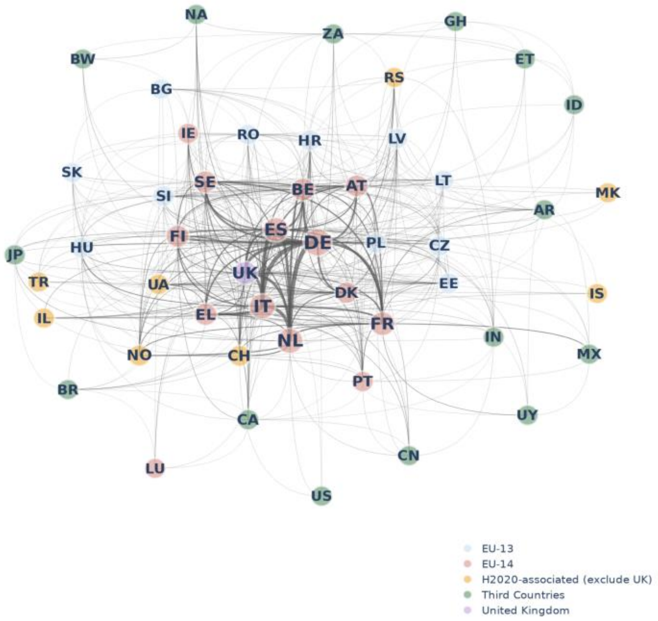

Figure 235. Network of participating countries in the Biofuels case study.

Source: eCorda, own calculation.

7.3.4.1. European Partnerships related to Biofuels

Through research and innovation (R&I) partnerships, the Framework Programme pools resources between the European Union (EU), the private sector and the Member States to tackle big challenges, support competitiveness and jobs, develop closer synergies with national and regional programmes, and encourage greater public and private investment in research and innovation. These partnerships were particularly successful in focusing transnational R&I activities on particular biofuel solutions and bringing research and industry stakeholders closer together in order to better understand each other's needs and requirements.

In terms of public-public partnerships, the ERA-NET Co-fund **BESTF3 Bioenergy Sustaining the Future** was analysed. The ERA-NET co-fund **BESTF3 Bioenergy Sustaining the Future** was active from January 2016 until December 2020. It built on BESTF ERA-NET Plus initiatives launched in 2013 (BESTF 1 and BESTF2, which were both funded through FP7) and also aimed at stimulating large-scale investments in enhanced biofuel technologies that are close to market readiness and commercialisation. The ERA-NET was funded under the WP 2014 – 2015 and received approximately 6.5 million Euros with an EC contribution of approximately 2.1 Million Euros. [141] It is a Public-to-Public (P2P) co-funded European partnership coordinated by the Department of Energy and Climate Change (DECC) in the UK.

It aims at contributing to achieving the objectives of the European Industrial Bioenergy Initiative (EIBI) Implementation Plan and the Strategic Energy Technology (SET) Plan. More specifically, its goals were to maintain and enhance coherence and networking between national bioenergy programmes, to advance the demonstration of enhanced bioenergy technologies and to support knowledge dissemination of the funded projects.

This ERA-Net issued a total of 4 calls over its runtime, and it funded 14 projects. On average, project consortia comprised 6.4 organisations. These were mostly organisations from the private sector (3 organisations on average per project) followed by Research organisations (I.6 organisations) and higher education organisations (1.2 organisations). This distribution reflects a focus on applied research on biofuel technologies that are closer to commercialisation and market uptake. In terms of participating countries, the average was organisations from 3 different countries. On top of the list is Austria, with the highest participation rate (14 project participations) on par with Sweden (14 project participations). Other participating countries were Denmark, Finland, Germany, Netherlands, Poland, Spain, Sweden as well as Taiwan.

7.4. Conclusions

E.Q 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

Most biofuels used today are first- generation which are those manufactured from food crops such as sugars and vegetable oils. The sustainability of first-generation biofuels is questionable as they compete with food crops, and some of these fuels have a relatively low environmental advantage compared to tradition fossil fuels. The emerging food crisis and the Russian invasion of Ukraine made the use of energy crops that compete with feed and food crops for the production of bioethanol or biodiesel even more problematic. On the other hand, this conflict also underscores the need to accelerate the independence from fossil fuels, where second-generation biofuels can play an important role.

Fuels with higher potential environmental benefits, particularly those associated with second-generation biofuels, exhibit lower cost-competitiveness, which hinders market uptake and reduces their potential contributions to Green Transition policy objectives. This is particularly challenging given that aviation and heavy-duty transport, as well as marine transport, require higher energy densities that only some biofuels can provide so that they can fully contribute to the achievement of the 90% transport emissions reduction by 2050, outlined in the European Green Deal. Of note is the waste-to-to-fuel technology, which produces energy-dense fuel, whilst also mitigating waste management issues and the negative environmental impacts of organic waste disposal.

Clearly, there is no panacea or silver bullet biofuel technology solution that can by itself make big advancements towards a green transition, and biofuels need to improve to be able to compete with fossil fuels in terms of costs or energy content. Consequently, exploration and exploitation of various fit-for-purpose biofuels in combination with the right political and market framework conditions will be

[141] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-search;callCode=H2020-LCE-2014-2015

crucial to make steps towards achieving the European Union policy priorities and rapidly decarbonising the transport sector.

E.Q 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of ‘innovation processes’ etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact?

This case study identified 2 internal factors and 3 external factors that have influenced progress in the biofuel area. The following section starts with 2 positive internal factors followed by three negative external factors.

First, the internationalisation of research teams was an internal success factor which brought highly specialised expertise of different parts of the biofuel value chain together. This factor also concerns bringing expertise and experience from geographically different biofuel contexts together, expediting knowledge co-production and knowledge transfer across Europe. Additionally, bringing research and industry stakeholders together helped to bridge the gap between research and implementation.

Second, given the long timeframes of developing new biofuel technology solutions and the time required to penetrate the market, another success factor was a strong commitment from an industrial stakeholder with strong expertise in biofuels. Projects with such a partner found it easier to overcome unexpected hurdles or delays during a project’s lifetime. Additionally, strong partners were also crucial in providing the financial capacity to carry project results forward once a project reached its end.

Third, one of the negative external factors that limited investments and market uptake in biofuels was the frequent changes in the political framework conditions at the European as well as national levels. For example, updates to existing directives (e.g. Renewable Energy Directive II, see section 2.2) had a strong influence on biofuel R&I through the introduction of criteria that differentiated between the sustainability of biofuels and introduced more difficult to attain sustainability standards along with the value chain. This prioritised the use of some biofuels over others (as well as a shift in emphasis on e-fuels and hydrogen, which is not part of this case study) and shifted the focus of R&I activities on ´favourable´ biofuels. These changing political priorities and the uncertainties that they induced were seen as creating unstable framework conditions for biofuels as well as fluctuating funding priorities for biofuel technologies. Taken together, these developments also created uncertainties for investors that damped investment interests. This is especially concerning given the large amounts of investment required for biofuel production capacities at scale. Overall, this negative external factor was, and still is, a major barrier to biofuels market uptake and integration, limiting the upscaling of project results.

Fourth, another negative external factor that hindered the progress of biofuels uptake is a lack of a commonly accepted methodology and accounting framework (e.g. life cycle assessment or Well-to-Wheel assessment) to reliably determine the costs and benefits of biofuels associated with their entire value chain (e.g. energy balance or greenhouse gas balance). Several methodologies with often fundamentally different assumptions were used by different projects and partners, which can pose a risk in terms of using certain methods to interpret results in a favourable way. The need for agreeing on the use of commonly accepted and standardised accounting and assessment methodologies was highlighted by interviewees, who also pointed to the importance of co-developing such a methodology with industry stakeholders.

Fifth, another negative external factor is the negative public perception of biofuels. Whilst this is largely associated with first-generation biofuels and their competition with food crops and indirect land use changes (also known as a “food vs. fuel” debate) as well as media reports on potentially negative effects on engine performance and longevity, the negative image that emerged in the past influences public discourse and thus political debate on biofuels until today.

E.Q. 4.3: *To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts?*

The communication and dissemination activities of projects were successful in promoting project activities and results. Also, the partnerships such as ETIP Bioenergy and EERA Bioenergy were undertaking communication and dissemination measures, albeit on a portfolio level. This helped to better communicate the current state of the art on biofuels research and innovation developments from an overarching perspective, thereby counteracting knowledge fragmentation and reducing redundancies between projects and the wider stakeholder community.

However, this case study also identified several measures that can help to improve communication, dissemination and exploitation in the future. For example, a stronger focus on communication and engagement measures with key stakeholder groups was identified as important (this could also be realised through dedicated communication & public engagement projects). Such interventions should focus on positive messaging about biofuels highlighting that today’s biofuels must adhere to comprehensive sustainability criteria, thereby addressing some of the negative public perceptions about biofuels that are still present. Likewise, addressing stakeholders that are not as closely linked to the biofuel community (e.g. investors, financers) could be intensified because these players are critical for uptake and upscaling but are often not aware of the latest developments. The challenge to reach important stakeholder groups, however, is to convey targeted messages in an already overcrowded and fast-paced communication and information space. Making better use of social media and the delivery of key messages with the option to easily access further information was flagged as a promising strategy.

Some projects were also successful in establishing a “brand name” during their project duration that was well recognised by the biofuel community. It would be beneficial if projects could keep their name when they continue, even in a different consortium constellation or activity focus, as this would help to maintain the communicative benefits that come with a well-known and immediately recognisable project acronym.

Lastly, more open communication about failures and the sharing of difficulties and hindrances in the development of new biofuel technologies would be beneficial. Such information would need to be made available to relevant stakeholders only, but it would be beneficial for the biofuel community at large as it would also help to increase the investment and resource efficiency of projects.

EQ 4.5. To what extent has international cooperation and, more specifically, association of third countries to the EU Framework Programme made a difference in achieving the environment related objectives of the Framework Programme?

Knowledge and practice exchange, as well as the testing of biofuel technologies in different contexts, is critical to ensure the continuous progression of biofuels and their wider application. This importance is reflected in the portfolio analysed, which had a 4.3% participation share of partners from third countries, which is more than double the average share of SC3 third-country partner participation. Similarly, third-country partners also received a larger average amount of EC contribution in the biofuels portfolio compared to the average in SC3.

This strategic focus on third-country participation is particularly valuable with countries that have a long history of biofuel R&I and market integration. In such cases, third-country partners complemented European expertise and provided insights into the requirements and dynamics of innovation systems that have a strong basis for biofuel research and implementation (e.g. bioethanol in Brazil).

EQ 5.1. What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

The EU added value of the Framework Program is particularly pronounced in its success in establishing a network of biofuels research and innovation experts. This is reflected in the institutionalisation of these networks like the European Technology and Innovation Platform (ETIP) Bioenergy or the European Energy Research Alliance (EERA) Bioenergy, which did not only support knowledge transfer and exchange between researchers and practitioners but also pursued trans-national policy support activities (e.g. ETIP Bioenergy on policy support for market integration of biofuels) for improving the alignment between the funding and political framework conditions at EU and national level. These partnerships were successful in focusing transnational R&I activities on biofuel solutions and bringing research and industry stakeholders closer together, creating a more direct link between research outputs and the application of new solutions under real-world conditions. They thereby helped in pooling knowledge and expertise and counteracting knowledge fragmentation.

Furthermore, the Framework Program was successful in establishing highly visible and well-recognised European projects which are internationally well-known. The Framework Program has thus helped to fund bigger and more prestigious projects, which national R&I funding would not necessarily have been able to achieve by itself either in terms of financial capacity as well as the pooling of know-how and expertise. Pooling European expertise combined with providing the financial capacity was particularly important for projects that aimed for large-scale production capacities.

Additionally, the Framework Program was successful in establishing new research lines, thereby setting the priorities for R&I activities in member states. This also helped to kickstart the formation of new research teams and to bring together experts from different parts of Europe.

An avenue to further improve the added value is to better link up to other EU and non-European funding opportunities that provide support along the entire innovation value chain and particularly when the project reaches its end and when promising results should be carried forward. While such complementary funding instruments are independent rather than fully integrated, there is a growing understanding that better-suited financing options are required. One example in this regard is the innovation fund which provides capital for the development of large-scale industrial power plants and first-of-a-kind production plants.

Furthermore, this case study identified the need to better ´track´ projects results and outputs once a project has finished. This would help to better understand what support measures are required after a project has finished, and it would provide important opportunities to make more informed adaptations to the work programs in the future.

7.5. Annexes

7.5.1. A.1 Key metadata of the case study

Table 68. Key metadata of case study no. 7 "Biofuels".

Case no. 7	**Biofuels**
Evaluation Question addressed*	EQ 4.2.; 4.3; 4.4.; 4.5.; 5.1.
Area	Energy
Programme parts	WP 2014-2015 (Energy) WP 2014- 2015 (SMEInst) WP 2016-2017 (Energy) WP 2016-2017 (SMEInst) WP 2018-2020 (Energy)
Scope	19 Horizon 2020 calls & 4 BESTF3 Bioenergy Sustaining the Future calls (ERA NETS) Time horizon covered: 2014 – 2020. 9 RIAs, 5 IAs, 3 CSAs, 2, SME Instruments and 4 BESTF3 ERA NET calls Number of projects analysed: 72
Key data sources	H2020 Work Programs & relevant call text BESTF3 Bioenergy Sustaining the Future call texts Project data from CORDIS & CORDA 5 interviews (3 Experts, 1 Policy Officer, 1 Project Beneficiary) Strategic Policy Documents (Set Plan Implementation Plan Action 8, STRIA roadmap for low-emission alternative energy for transport (ALT); EERA Bioenergy Strategic Research and Innovation Agenda; ETIP Bioenergy Strategic Research and Innovation Agenda)
Links with partnerships	BESTF3 Bioenergy Sustaining the Future and related ERA-NET Cofund Calls: Bioenergy Sustaining the Future (2015) Bioenergy as part of a smart and flexible energy system (2016) Biomass as an important pillar within energy systems and the circular economy (2017) Combined biomass valorisation to bioenergy, industrial feedstocks and bio based products (2018)
Relevant policies	European Green Deal Climate Target Plan European Strategic Energy Technology Plan (SET Plan) – Action 8 Renewable Energy Direction (RED II) Clean Energy for all Europeans Package Indirect Land Use Change (ILUC) Directive Fuel Quality Directive

Table 69. Project information.

Project Acronym	Action Type	Project Call ID	Participants	EC Net Contribution
2G BIOPIC	IA	H2020-LCE-2014-2	9	1,865,411
4AirCRAFT	RIA	H2020-LC-SC3-2020-NZE-RES-CC	10	1,829,391
4REFINERY	RIA	H2020-LCE-2016-RES-CCS-RIA	11	1,809,586
ABC-SALT	RIA	H2020-LCE-2017-RES-RIA-TwoStage	13	1,540,714
ADVANCEFUEL	CSA	H2020-LCE-2017-RES-CSA	12	1,872,912
Ambition	RIA	H2020-LCE-2016-ERA	8	709,468
BABET-REAL5	RIA	H2020-LCE-2015-1-two-stage	9	1,998,918
BECOOL	RIA	H2020-LCE-2016-RES-IA	12	1,992,920
BIKE	CSA	H2020-LC-SC3-2020-RES-IA-CSA	8	1,897,438
Bin2Grid	CSA	H2020-LCE-2014-3	13	1,999,885
BIO4A	IA	H2020-LCE-2017-RES-IA	11	1,971,610
Bioenergy4Business	CSA	H2020-LCE-2014-3	12	1,941,581
BiogasAction	CSA	H2020-LCE-2015-3	8	1,629,884
Biomasud Plus	CSA	H2020-LCE-2015-3	5	1,480,535
BioMates	RIA	H2020-LCE-2016-RES-CCS-RIA	4	599,105
BioRen	RIA	H2020-LC-SC3-2018-RES-SingleStage	10	2,628,246
BioRES	CSA	H2020-LCE-2014-3	34	3,000,485
BioSFerA	RIA	H2020-LC-SC3-2019-NZE-RES-CC	13	2,998,181
BIOSURF	CSA	H2020-LCE-2014-3	16	2,970,419
BioValue	SME-2	H2020-SMEINST-2-2014	15	9,937,771
BioVill	CSA	H2020-LCE-2015-3	7	10,192,516
BL2F	RIA	H2020-LC-SC3-2019-NZE-RES-CC	8	19,999,544
ButaNexT	RIA	H2020-LCE-2014-1	13	12,250,528
CERESiS	RIA	H2020-LC-SC3-2020-RES-RIA	7	11,472,916
CLARA	RIA	H2020-LC-SC3-2018-RES-SingleStage	9	10,002,520
COMSYN	RIA	H2020-LCE-2016-RES-CCS-RIA	13	13,856,302
CONVERGE	RIA	H2020-LC-SC3-2018-RES-SingleStage	18	9,999,733
DiBiCoo	CSA	H2020-LC-SC3-2019-RES-IA-CSA	7	20,000,000
EBIO	RIA	H2020-LC-SC3-2020-RES-RIA	9	3,988,604
EcoFuel	RIA	H2020-LC-SC3-2020-RES-RIA	9	3,994,323
eForFuel	RIA	H2020-LCE-2017-RES-RIA-TwoStage	9	4,858,548
EHLCATHOL	RIA	H2020-LC-SC3-2020-RES-RIA	12	3,564,700
ETIP Bioenergy-SABS	CSA	H2020-LCE-2016-ETP	8	3,999,629
EUCANwin	RIA	H2020-LC-SC3-2020-NZE-RES-CC	11	4,998,788
FLEDGED	RIA	H2020-LCE-2016-RES-CCS-RIA	20	2,999,950
FLEXI-GREEN FUELS	RIA	H2020-LC-SC3-2020-RES-RIA	17	4,031,100
FlexSNG	RIA	H2020-LC-SC3-2020-NZE-RES-CC	13	3,993,006
FLITE	IA	H2020-LC-SC3-2019-RES-IA-CSA	12	4,230,810
FORBIO	CSA	H2020-LCE-2015-3	11	4,448,839
GLAMOUR	RIA	H2020-LC-SC3-2019-NZE-RES-CC	9	2,239,591
GOLD	RIA	H2020-LC-SC3-2020-RES-RIA	8	2,846,079
GreenFlexJET	IA	H2020-LCE-2017-RES-IA	11	3,534,034
greenGain	CSA	H2020-LCE-2014-3	12	4,599,414
Heat-To-Fuel	RIA	H2020-LCE-2017-RES-CCS-RIA	14	5,998,251

HIGFLY	RIA	H2020-LC-SC3-2020-RES-RIA	13	5,999,893
HyFlexFuel	RIA	H2020-LCE-2017-RES-CCS-RIA	19	5,573,644
IDEALFUEL	RIA	H2020-LC-SC3-2019-NZE-RES-CC	10	4,450,618
ISAAC	CSA	H2020-LCE-2015-3	23	5,989,743
ISABEL	CSA	H2020-LCE-2015-3	9	5,923,316
KEROGREEN	RIA	H2020-LCE-2017-RES-RIA-TwoStage	9	5,096,660
LAURELIN	RIA	H2020-LC-SC3-2020-NZE-RES-CC	10	5,965,474
MacroFuels	RIA	H2020-LCE-2015-1-two-stage	11	5,306,455
NextGenRoadFuels	RIA	H2020-LC-SC3-2018-RES-SingleStage	10	2,494,986

Table 70. Table of Horizon 2020 calls analysed.

Work programme	Call title	Instrument	No. of projects
WP 2014-2015 (Energy)	LCE 11 – 2014/2015: Developing next generation technologies for biofuels and sustainable alternative fuels	RIA	6
	LCE 12 – 2014/2015: Demonstrating advanced biofuel technologies:	IA	2
	LCE 14 – 2014/2015: Market uptake of existing and emerging sustainable bioenergy	CSA	14
WP 2014- 2015 (SMEInst)	Stimulating the innovation potential of SMEs for a low carbon energy system	SME 2	1
WP 2016-2017 (Energy)	LCE-06-2017: New knowledge and technologies Projects under this call address several areas, of interest are those on "Sustainable fuels"	RIA	5
	LCE-08-2016-2017: Development of next generation biofuel technologies	RIA	6
	LCE-19-2016-2017: Demonstration of the most promising advanced biofuel pathways	IA	3
	LCE-20-2016-2017: Enabling pre-commercial production of advanced aviation biofuel	IA	2
	LCE-21-2017: Market uptake of renewable energy technologies Projects under this call address several areas, of interest are those on "Sustainable fuels"	CSA	1
WP 2016-2017 (SMEInst)	Stimulating the innovation potential of SMEs for a low carbon and efficient energy system	SME 2	1
WP 2018-2020 (Energy)	LC-SC3-RES-21-2018: Development of next generation biofuels and alternative renewable fuel technologies for road transport	RIA	7
	LC-SC3-RES-23-2019: Development of next generation biofuel and alternative renewable fuel technologies for aviation and shipping	RIA	5
	LC-SC3-RES-24-2019: Boosting pre-commercial production of advanced aviation biofuels	IA	1
	LC-SC3-RES-25-2020: International cooperation with Japan for Research and Innovation on advanced biofuels and alternative renewable fuels	RIA	4
	LC-SC3-RES-26-2020: Development of next generation renewable fuel technologies from CO2 and renewable energy (Power and Energy to Renewable Fuels)	RIA	3
	LC-SC3-RES-27-2020: Demonstration of advanced biofuels production from aquatic biomass	IA	1
	LC-SC3-RES-28-2018-2019-2020: Market Uptake support Projects under this call address several areas, of interest are those on "renewable fuels"	CSA	3
	LC-SC3-RES-36-2020: International cooperation with Canada on advanced biofuels and bioenergy	RIA	3
	LC-SC3-RES-37-2020: Combined clean biofuel production and phytoremediation solutions from contaminated lands worldwide	RIA	4

7.5.2. Overview of related ERA-NETs

In addition to the above project portfolio, 4 calls of the ERA NET Co-fund BESTF3 Bioenergy Sustaining the Future were analysed:

Table 71. BESTF3 calls analysed.

BESTF3 Bioenergy Sustaining the Future Call Name	Month & Year the call opened	Number of projects funded
Bioenergy Sustaining the Future 3	Dec. 2015	3
Bioenergy as part of a smart and flexible energy system	Oct. 2016	6
Biomass as an important pillar within energy systems and the circular economy	Oct. 2017	2
Combined biomass valorisation to bioenergy, industrial feedstocks and bio-based products	Oct. 2018	3

8. Case study 8: Towards very-low emission and lightweight vessels

8.1. Summary

The case study investigates the activities linked to very low-emission and lightweight vessels in the waterborne sector. This includes new types of marine engines, fully electrically powered ships, exploitation activities in the shipping sector for market uptake and demonstrating the viability of the technologies and the realisation and demonstration of advanced material solutions for sustainable and efficient ships.

The case study has shown that the projects analysed have contributed to reducing waterborne transport-related CO2 emissions and to reaching the market readiness of new solutions. The analysed project portfolio consisted of Innovation Actions (IAs) that demonstrated through demonstrator projects that the implementation of new technological solutions or the introduction of advanced materials in ships is possible. In addition, new standards and legal framework conditions were developed or impulses for those were generated. It became apparent that, in addition to the technological factors and new or adapted standards and/or regulations, the collaboration across projects, the formation of networks, the composition of the consortium and the support from the EC contributed greatly to the success of the projects. The case study also showed that knowledge and technology transfer between projects and between different sectors are important factors that have a beneficial impact on the outcome of the projects.

8.2. Introduction and overview

8.2.1. Objectives

The case study "very-low emission and lightweight vessels" analyses relevant innovation actions (IAs) funded under Horizon 2020 that are related to the ambition to increase the efficiency and sustainability of waterborne transport. The analysed activities are related to the development of different fuel types, propulsion systems and new materials to make shipping more environmentally friendly and resource-efficient. The case study topic is, therefore, highly relevant from a green transition perspective, as the case during Horizon 2020 was embedded in Societal Challenge 4, which aimed, as part of its objectives, to make transport more sustainable and resource-efficient. The overall objective of this case study is to examine the key outcomes, results, enabling and constraining factors of the projects funded under H2020 and to analyse the extent to which Horizon 2020 interventions have enabled an effective approach to more efficient and sustainable waterborne transport that can be further scaled up in Horizon Europe.

In the H2020 calls, all three work programs (2014-2020) already reflect the relevance of decarbonization goals in the waterborne sector by contributing to strategic research, development and innovation developments and promoting Europe's leadership in waterborne vehicle design, production and operation. Therefore, the case study on very-low emission and lightweight vessels is a highly relevant example of how the topic has progressed during seven years of investments in research and innovation towards zero-emission waterborne transport, which took place in the framework of H2020. In order to assess whether the ambitious goals of the Framework Program have been sufficiently achieved by Horizon 2020 research and innovation projects and what can be enhanced in Horizon Europe, the case study has the following objectives:

- Identifying the main outputs and impacts of the projects in the intervention area
- Identifying drivers and barriers for the implementation and market uptake of new technological solutions, propulsion systems and materials in the waterborne sector
- Internal and external factors that allowed for success or hindered success and/or challenges of the research and/or demonstration activities
- The adequacy of the EC implementation measures and the identification of research needs
- Determine the EU added value vis-à-vis national funding

8.2.2. Methodology and case study structure

The analytical approach commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to Sustainable Transport and Mobility (e.g., Transport White Paper 2011, Sustainable And Smart Mobility Strategy Putting European transport on track for the future, 2021). This led to the identification of four areas of interest for the Green Transition: a) More sustainable modes of transport, b) More sustainable alternatives (supply side), c) More sustainable choices (demand side), and d) Reducing pollution and risk. The case study “Towards very-low emission and lightweight vessels” is part of the case studies covering area a).

The focus of this analysis is on two Horizon 2020 calls and, within them on 5 funded R&I projects (Innovation Actions - IA) that dealt with new types of marine engines, fully electric powered ships, analysis of previous research results and exploitation activities in the marine sector, market acceptance and proof of the viability of the technologies, and realization and demonstration of advanced material solutions for sustainable and efficient ships. Moreover, the case study includes projects that have a medium to high technological readiness level (TRL) and enablers and barriers can therefore be analysed from the development of the components to the deployment of the vessels. An overview is provided in the Annex of this case study. The case study is based on data analysis and document review, completed by interviews with beneficiaries as well as experts in the field of very-low emission and lightweight waterborne transport. The approach of this case study included first the analysis of the H2020 work programs, relevant call texts and strategic documents related to sustainable and resource-efficient waterborne transport. Subsequently, the relevant project actions in Horizon 2020 were identified in the work programs. Relevant and available project-specific data were compiled and analysed by Cordis/Corda and complemented by additional sources such as project websites.

In addition to the analysis of project data, 6 interviews were conducted with relevant thematic experts in the field of sustainable shipping technologies and with beneficiaries and project coordinators of the selected five H2020 R&D projects. The interviews followed a semi-structured, exploratory approach based on guidelines related to the evaluation questions in focus. The results of the interviews were triangulated and analysed with respect to the evaluation questions of the study.

8.3. Synthesis of evidence

Shipping is considered one of the most important pillars of the global economy. Around 80-90% of all world trade is not conducted by land or air but by sea. Overall, shipping emissions account for about 3% of annual greenhouse gas emissions and are projected to increase about 90-130% compared to 2008 emissions by 2050, according to a study by the International Maritime Organization (IMO) (IMO, 2020). In Europe, the shipping sector is responsible for 13.4% of greenhouse gas emissions from the European transport sector due to their large scale as a mode of transport (European Commission, 2019).

Traditional shipping is still powered by large diesel engines, which are major contributors to air pollution through high emissions of sulfur oxides (SOx), nitrogen oxides (NOx), and particulate matter (PM). This makes shipping the largest air polluter, in contrast to other modes of transport. Given its fundamental importance to the European economy and its global nature, efforts are needed to reduce its environmental impact. This is because the maritime sector is one of the most difficult sectors to decarbonize due to the lack of readily available solutions and also because the typical long lifetime of ships imposes a long period of time before the effects of possible measures become visible (Grosso et al., 2021).

8.3.1. Strategic policy priorities

The EU has a key role to play in reducing emissions from shipping by adopting regulatory measures, providing financial incentives and promoting R&I activities to develop and/or improve innovative technologies, as well as support and coordination measures.

Back in 2009, the European Commission presented the European Maritime Transport Strategy from 2009 up to 2018, which already at that time aimed to make the water transport sector more competitive and sustainable. The EU Member States and the European shipping industry were already urged in the 2009 Communication to work together towards the long-term goal of zero-emission maritime transport. Furthermore, it was already made clear at that time that the interaction and interdependencies between the various actors in the maritime sector are becoming increasingly important. Therefore, it was a concern to facilitate cooperation and operational collaboration between the different maritime stakeholders (European Commission, 2009).

A White Paper for Transport adopted by the Commission in 2011 specifies the orientations of the Maritime Transport Strategy until 2018. The guidelines presented therein focused mainly on the long-term competitiveness of the EU shipping sector and the creation of seamless transport chains for passengers and cargo, as well as the provision of cost-effective maritime transport services. Then in 2016, the progress of the implementation of the Maritime Transport Strategy 2009 was presented by the European Commission, and further measures were drawn up, including " Environmental Sustainability and Decarbonisation " (European Commission, 2016).

In the latest EU strategy on mobility, the "Sustainable and Smart Mobility Strategy 2020", a strong emphasis has been placed on measures that are in line with the objectives of the European Green Deal. For the maritime transport sector, special attention has been given in this context to promoting the production and introduction of sustainable and alternative marine fuels, as well as the development of zero-emission and environmentally friendly ships and innovative technologies. This also includes, in particular, reducing market barriers and increasing the market maturity of innovative propulsion technologies and fuels (European Commission, 2020). Furthermore, it is important to emphasize that the EU measures should always keep in mind the international competitiveness of EU-flagged ships, as this must not be undermined by the targets. Additionally, EU and international measures should go side by side in order to avoid duplication of regulations (Bilbao-Ubillos et al., 2021). In order to achieve these ambitious goals, the newly established "Zero Emission Waterborne Transport" partnership will also play an essential role in the context of the new EU Horizon Europe research framework program. Future R&I activities will hence focus on the following areas that have been defined for the partnership: increased use of sustainable alternative fuels, electrification, increased energy efficiency, design and retrofit solutions for the new and existing fleet, digital green solutions to improve efficiency, and sustainable bunkering and loading solutions for climate-neutral ships. In addition, the partnership will make efforts to leverage a range of dedicated measures such as private investment, the Connecting Europe Facility (CEF), the Climate Innovation Fund, regional funds and many more.

8.3.2. Horizon 2020 programming related to very-low-emission and lightweight vessels

In H2020, all three work programs (2014-2020) already reflect the relevance of the above-mentioned policy and decarbonization goals in the waterborne sector by contributing to strategic research, development and innovation developments and promoting Europe's leadership in waterborne vehicle design, production and operation. The topic of very low-emission and lightweight vessels was addressed mainly within the H2020 transport challenge anchored in Societal Challenge 4, which specifically aimed to make transport more sustainable and resource-efficient.

In the context of the sustainable development of maritime shipping, the 2014/2015 work program focused primarily on the optimal use of energy sources and the minimization of environmental impact, particularly with regard to pollutant and greenhouse gas emissions from ships. In particular, this research framework program supported technological solutions involving four ship subsystems: Engine, Pollution Control Systems, Propulsion, New and Sustainable Energy Sources, and Management, including the efficient operation of on-board systems. The goal should be to demonstrate the feasibility of an or near-zero-emission ship. In addition, the solutions should be close enough to market readiness that ship owners will consider these concepts in their future investment plans.

The 2016-2017 Work Program highlighted that the challenges for shipping are the three pillars of sustainability (Economic, Environmental, Social), and there is a need for a modern, resource-efficient, connected, safe and resilient water transportation system. The focus was on efficiency improvements, improved use of energy sources, minimizing the environmental impact of vessels, and introducing new lightweight and high-performance materials, including the design and manufacture of vessels and components. Another objective was to develop European leadership in the design, production and operation of ships and waterborne assets. In addition, the current priorities of stakeholders should be considered, and input to regulatory regimes should be generated where necessary.

In contrast to the two previous work programs, waterborne is no longer a stand-alone topic in the 2018 Research Framework Program but can be found in the “Mobility for growth” call “Building a low-carbon, climate-resilient future: low-carbon and sustainable transport and safe, integrated and resilient transport system”. In this work program, there was a major focus on retrofit technologies and new propulsion technologies for shipping. In particular, the new innovations were intended to improve existing fleets and make them more efficient over the next five to ten years. There was also a focus on reducing Co2 and air pollutant emissions from intra-European freight transport. There was again the focus on improving European competitiveness and facilitating the use of innovative environmentally friendly technologies for shipping. In addition, a call for the establishment of a partnership was made for the first time in this Framework Program to strengthen the uptake and visibility of R&I results.

Summarized, the work programs seek to ensure that research and innovation activities enable pilot applications and demonstrators for new engines, new pollution reduction technologies, new powertrains and alternative materials, and fuel solutions to be ready for market uptake by the end of the research period.

For the purpose of getting to a useful and meaningful assessment of the H2020 contributions to the topic of very-low and lightweight vessels, the following calls from the work programmes 2014/2015 and 2016/2017 have been identified for analysis:

H2020 call	Specific Challenge	Expected Impact
MG-4.1-2014 - Towards the energy efficient and emission free vessel	The challenge is to support developments that make new and existing vessels used in maritime operations (including leisure) and in inland navigation significantly more efficient and less polluting through solutions addressing four ship sub-systems: engine, pollution abatement systems, propulsion, energy sources and management including the efficient operation of on-board systems. Waterborne transport still offers an enormous potential for pollution reduction and energy efficiency gains. The reduction of pollutant and greenhouse gas emissions is far removed from the progress made in road transport, particularly in the category of older, small to medium-size vessels which make up a large proportion of intra-European waterborne transport, including inland navigation. Since vessels have a long life expectancy, developing technologies for clean retrofit and fuel conversion solutions is a key aspect of the challenge.	Achieve efficiency gains and emission reductions that go significantly beyond normal technological progress and the benchmarks of the existing regulatory regimes at lowest costs. • Achieve fuel efficiency gains of at least 15% for retrofitting per type of solution (engine or propulsion) and at least 30% per type of solution for new concepts. • Accomplish a 25% decrease in greenhouse gas emissions and a reduction of, on average, 80% in air pollution compared with Best Available Technology (BAT). Experience acquired in this innovative field should be broadly made available to ship owners requiring improvements in the environmental performance of their vessel.
MG-2.2-2016 - Development, production and use of high performance and lightweight materials for vessels and equipment	New lightweight materials and related construction principles can provide a step change in vessel efficiency, both in terms of energy use and maintenance costs. European technology leadership in this field (often held by innovative SMEs whose effective integration in the value chain is essential) needs to be translated into market demand in current and future markets, also beyond the maritime transport sector. The specific challenges are to research the functional characteristics of new lightweight and high performance materials for waterborne usages (vessels and components); to develop the most appropriate design, construction and production principles for small, medium sized and large vessels and for components (also by learning from applications in other transport modes); and to influence the regulatory environment in order to eliminate existing barriers and facilitate market take-up in the waterborne sector.	Activities will introduce new lightweight and high performance materials in waterborne applications through the demonstration of full feasibility of the use of such advanced materials, including design and production of vessels and components; through proving significantly lower maintenance and life cycle costs (at least -30% compared to conventional materials and processes); through the development of clear performance indicators (especially with regard to economic and environmental impacts) covering the entire life cycle; and through demonstrators (full scale where feasible) for clearly identified maritime applications. Inputs to pertinent regulatory regimes should be developed where applicable and necessary.

The selected calls and the associated expected impacts and specific challenges provide the framework for the objectives of the work programme related to very low-emission and lightweight vessels. The analysis of the case study will provide answers to how much the projects have contributed to these expected impacts and specific challenges.

8.3.3. Project portfolio characteristics

8.3.3.1. Horizon 2020 project portfolio

Overall, the project portfolio of this case study comprises 5 projects related to very-low emission and lightweight vessels, which have already been completed. The projects covered in this study, resulting from the H2020 programme calls, include 5 projects that have already been completed. The projects under consideration comprised EC net contributions of 67 Mio. € and all projects are Innovation Actions (IA).

Table 72. Type of organisations in Case Study very-low emission and lightweight vessels.

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1000)
		Nb	Share (%)	EUR (1000)	Share (%)	
HES	4	25	16%	10.357	15%	414,3
OTH	1	1	1%	81	0%	81,4
PRC	5	105	67%	42.647	63%	406,2
PUB	1	2	1%	3.041	5%	1.520,6
REC	5	24	15%	11.245	17%	468,6
Total (All types)	**5**	**157**	**100%**	**67.373**	**100%**	**429,1**

HES: Higher or Secondary Education Establishments

PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)

REC: Research Organisations

PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)

OTH: Other

Source: eCorda, own calculation.

As shown in Table 74, more than half of the net EC contribution (63%) and thus the largest share of the allocation falls to private companies. Further, 17% was allocated to research institutions, 15% to higher education institutions, 5% to public institutions and a very small amount to an association. Compared to other Green Transition areas examined in this study (SC2 to SC5), this portfolio has one of the highest shares of funding for for-profit organizations, indicating a particularly high relevance for private actors (shipping companies, shipyards, etc.) participating in the calls. However, the high shares of funding for for-profit entities can also be explained by the fact that in this case study, all projects were Innovation Actions (IAs), and IAs usually involve a relatively large number of private entities. Figure 1 shows that a total of 67% of private companies were involved in the projects, followed by higher education establishments (16%) and research organizations (15%). Public bodies had the lowest participation and were involved in only one project (E-ferry). An association was also involved, namely the “Shipyards and maritime equipment association of Europe” in the LeanShips project.

Table 73. Group of countries of the case study very-low emission and lightweight vessels.

Group of country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Number of countries
		Nb	Share (%)	EUR (1,000)	Share (%)		
H2020-EU27	5	138	87.9%	64,856	96.3%	470.0	17
EU-14	*5*	*125*	*79.6%*	*62,756*	*93.1%*	*502.0*	*12*
EU-13	*3*	*13*	*8.3%*	*2,101*	*3.1%*	*161.6*	*5*
H2020-associated (exclude UK)	3	10	6.4%	305	0.5%	30.5	2
United Kingdom	4	9	5.7%	2,211	3.3%	245.7	1
Third Countries	0	0	0.0%	0	0.0%	N/A	0
All-countries	**5**	**157**	**100.0%**	**67,373**	**100.0%**	**429.1**	**20**

As Table 75 shows, the beneficiaries involved in the 5 projects were predominantly (88%) from EU-27 countries, with 80% of participants from EU-14 countries and just over 8% from EU-13 countries. The participation of EU-13 countries is thus just above the average of 6% compared to all Horizon 2020 projects in this Green Transition study. In addition to EU-14 and EU-13 countries, the UK was involved in 4 projects and associated countries in three projects. It can be observed that although the UK was involved in 4 projects, it only received around 6% of the total budget. Similarly, associated countries received a very small share of just under 3% of the total budget. Third countries were not involved in any of the projects. All 5 projects were also coordinated by EU-14 countries (Italy, Netherlands, Denmark, Greece, Spain).

Table 74. Top countries in case study very-low emission and lightweight vessels.

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)
		Nb	Share (%)	EUR (1,000)	Share (%)	
Finland	5	10	6.4%	8,799	13%	879.9
Greece	4	5	3.2%	1,864	3%	372.8
Denmark	4	10	6.4%	11,455	17%	1,145.5
Spain	4	13	8.3%	4,120	6%	316.9
Netherlands	4	21	13.4%	7,253	11%	345.4
United Kingdom	4	9	5.7%	2,211	3%	245.7
Italy	4	12	7.6%	3,586	5%	298.8
Germany	4	25	15.9%	16,150	24%	646.0
Switzerland	3	7	4.5%	159	0%	22.7
France	3	15	9.6%	6,094	9%	406.3
Sweden	3	7	4.5%	1,889	3%	269.8
Romania	2	3	1.9%	668	1%	222.7
Norway	2	3	1.9%	146	0%	48.6
Estonia	2	6	3.8%	853	1%	142.1
Belgium	1	5	3.2%	673	1%	134.6
Cyprus	1	1	0.6%	338	1%	337.8
Austria	1	1	0.6%	150	0%	150.0
Croatia	1	2	1.3%	137	0%	68.4
Hungary	1	1	0.6%	105	0%	105.2
Ireland	1	1	0.6%	723	1%	722.8

In terms of country participation, Finland was the only country to participate in all of the 5 projects but did not receive the largest share of the EC amount in the total funding, instead receiving only the third highest amount at 13%. Germany received the highest contribution of total EC funding with a share of 24%, followed by Denmark with 17%.

The network analysis of the participating countries on the next page shows that there was the strongest exchange between the EU-14 countries Netherlands, Germany, Spain, France, Finland and Italy. There was also close cooperation and exchange between Greece, Sweden, the United Kingdom and the EU-13 country Estonia. There were far fewer close ties with the associated countries, Norway and Switzerland.

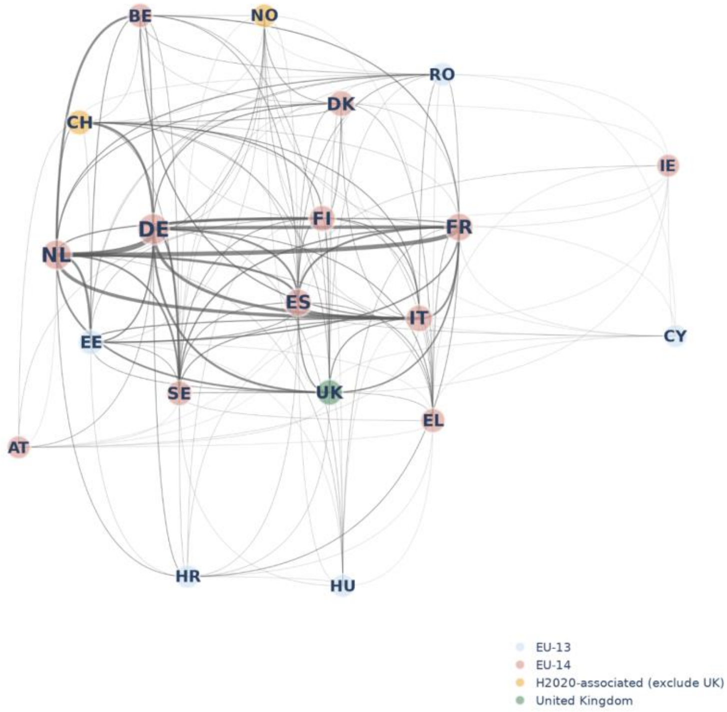

Figure 236 Network of participating countries in case study very-low emission and lightweight vessels.

Source: eCorda, own calculation.

8.3.3.2. Results of the Horizon 2020 funding activities: pathways to impact

All analysed projects addressed multiple outcomes of the five pathways shown in figure 255. Based upon the Work Programme analysis, Figure 255 provides an overview of pathways to impact identified in the analysis regarding transport and mobility.

Coordination & Collaboration	Knowledge & Capacity	Market & Business	Technology & Innovation	Policy & Standards
• Stronger pan-European collaboration across disciplines, sectors, value chains and technology levels • Cross-border and cross-sector coordination and integration of R&I efforts	• Better understanding of local and regional specificities , user behaviour and perceptions • New European multimodal transport management systems • More service oriented transport System • Access to new knowledge	• More competitive and cooperative Industry • Access to new Markets • More sustainable manufacturing of innovative systems and equipment	• Comprehensive, intermodal and appropriate systemic solutions • New European Information and payment systems • New generation of innovative and environmentally friendly air, waterborne and land transport means • Efficient interfaces between long distance and urban mobility networks	• More informed transport policies • New transport standards

Figure 255. Expected Outcomes across all analysed calls.

The following section provides a detailed analysis of the analysed project outcomes under the five pathways.

Coordination and Collaboration Pathway

Collaboration with relevant maritime stakeholders, as well as coordination activities, including networking activities, played a key role in the projects investigated. Involving stakeholders from the maritime industry, such as technology manufacturers, ship owners, certification bodies, or shipyards, in the projects is essential for research, development and market acceptance and led to great successes in the respective projects. In addition, the collaboration of market competitors, for example, as in the HERCULES-2 project, played a major role in the success of the project. Involvement and cooperation with commercial partners are therefore immensely important for the future development of the vessels and market uptake, as one interviewee pointed out:

"But it also helps to have partners that you work with also in commercial projects, because the more the consortium looks like a consortium that could be working on a commercial project, the higher the probability that in the future the knowledge build up during the project and the relationships will translate into more innovative and green vessels." – Project beneficiary

However, it was also noted that it is not so easy to get especially ship owners to participate in research projects. This is mainly related to the emphasis on the need for the commercial benefits of activities. The challenge here is also that the interest in certain technologies may change during a project period, or another technology may evolve in a way that makes it more interesting for commercial use by ship owners. As this quote from an interviewee illustrates:

"They [the shipowners] say we will invest in the technology that is currently mature and gives us advantages. And then when better technologies are available, we will invest in the other or better technologies in the next phase." – Thematic Expert

It is, therefore, essential for cooperation that the involved partners from industry and the maritime sector, as well as public organizations and certification bodies, believe in the feasibility and commercial benefits of the concept and show their support for sustainable transport solutions on the water. In addition, some interviewees indicated that in the future, cooperation will become increasingly important, especially with ports, as a new infrastructure will have to be built to accommodate the new vessels.

The importance of establishing networks was also seen by some interviewees as crucial to connect with maritime stakeholders, industry experts or other projects and to support each other's efforts. Here, for example, there was the ELAS network, for which the RAMSSES project had reserved a budget to organize meetings with maritime stakeholders. Through this network, they were able to increase the number of participants in this network and also keep relevant stakeholders informed of the project's progress. This helped the project in dissemination to get feedback from various stakeholders, such as ship owners. For the organization and maintenance of such networks or even platforms, it is crucial that EU funds are made available. Some interviewees remarked that it would also be important to have financial support after the end of the project in order to maintain these networks more easily and to promote the exchange in the long term. This will also help future projects in particular, which can exchange information in such networks or platforms and also obtain feedback on their projects. In the future, the newly established Partnership "Zero Emission Waterborne Transport" could help facilitate and strengthen exchange and collaboration. However, it was also noted that it needs to be easy to become a partner in this partnership, and there should be more campaigns inviting to become a member and explaining the process and giving an overview.

In addition to the collaboration within the projects with maritime stakeholders, it was also very helpful for some of the interviewees to collaborate across projects with other H2020 projects, especially from the same calls. For example, collaboration with projects working on similar challenges was very present in the RAMSSES and FIBRESHIP projects. Both projects were striving to find solutions for innovative materials and faced the challenge of the material regulations currently in place and the lengthy processes of certifications. The collaboration of the two projects brought success in this regard as they worked together to present their research, as well as proposals for the implementation of a smart track to approval (STTA) to the IMO. By drawing on existing regulations and allowing the reuse of information and results from previous safety assessments, STTA becomes a valuable resource for both rule- and policymakers. Another example of cross-project collaboration was between the E-Ferry, LeanShips, and RAMSSES projects. Synergies and collaboration between the projects made it possible to improve the exchange of knowledge and pave the way for solutions to problems more quickly.

Knowledge and Capacity Pathway

Given that the projects analysed were all IAs and focused on the development of demonstrators, the focus was primarily on close-to-market solutions. However, building knowledge and especially expanding the knowledge base played a significant role in all of the projects analysed. The projects provided the shipbuilding industry with a lot of knowledge through their demonstrator ships with new design specifications that meet the requirements of the market. However, it also became clear in some projects that more knowledge building is needed, especially at a lower TRL, to make certain technologies or materials truly marketable. One interviewee stated that after such knowledge-building, there should also be direct and easier access to CEF projects. This would help to ensure that this knowledge can then be transferred more effectively into demonstration projects. As a result, shipyards and shipping companies could more easily venture into high-risk demonstrator projects in the future.

Knowledge building was furthermore facilitated by knowledge sharing and technology transfer from other industries in some projects. For example, in the RAMSSES project, there was a cross-sector exchange of ideas and experience, especially with partners from the aerospace industry, which helped in the development and organization of production processes. Learning from other industries thus proved particularly fruitful, as this quote illustrates:

> *„Yeah, I wanted to add one of the success points - maybe it's just a more precise explanation of what I already said - we had this technology transfer aspect which was also very good." – Project beneficiary*

In addition to external knowledge exchange and technology transfer, however, knowledge exchange within the project team was also seen as relevant by some interviewees. The different experiences of the project partners involved helped to solve the challenges in an intelligent way by exchanging different positions, which means that the composition of the project partners and their regular exchange of tasks and challenges are of enormous importance.

Policy and Standards Pathway

All the projects analysed helped to pave the way for new standards and policy measures to encourage ship operators to adopt the new materials and propulsion technologies. For example, the E-Ferry project has shown that it is possible to operate fully electric passenger ferries. The reason that it is possible for the E-ferry to continue in operation is mainly due to the fact that the concept of an electric, zero-emission ferry contributes to policy goals towards climate neutrality on the island of Aero in Denmark. In addition, E-Ferry has managed to obtain approval from the maritime authority to operate the electric ferry, which was a lengthy process as such legal procedures had to be created first.

In all projects, inputs were made to standardization efforts in terms of technical requirements. Also, in some projects, a special focus was placed on design guidelines and easy-to-use standards and rules for new materials. Here, communication with international shipping authorities was particularly necessary to communicate the benefits of new testing standards and to ensure the review of preliminary guidelines. Regarding the definition of new standards, however, it also became apparent in some cases that some things still need to be better understood in order to establish new standards. In particular, this was evident in the use of innovative materials and the safety rules on fire protection. There is still discussion on how to establish new test procedures to subject the materials to a fire test in a meaningful way. Despite the fire safety properties of the new materials and regulatory challenges that still have to be overcome, the FIBRESHIP and RAMSSES projects have shown that it will soon be possible to build sustainable ships on a large scale using new innovative materials. The two projects have also contributed, as described in the coordination and collaboration pathway, through their joint STAA proposal to the IMO to accelerate changes and modifications to certain standards. Nevertheless, more work may need to be done at the international level to review and possibly revise regulations to allow the use of advanced materials in larger ships. Policy measures could also support faster commercialization of the new ships or technological solutions.

Market and business Pathway

The results of the projects were all able to demonstrate an improvement in the marketability and feasibility of efficient and low-emission shipping. The focus of the projects analysed was to demonstrate marketability and feasibility through the demonstration activities, as well as to promote customer acceptance and replication. Respondents emphasized that they have all produced tangible results in terms of new business models in the field of very-low emission and lightweight vessels, which has brought an improvement in the competitiveness of the European ship operators and shipbuilding industry. The results ranged from cost-benefit analysis and the elaboration of a business plan end-users assessment and supply chain evaluation. Results of the market surveys and business plans can be capitalized and used in terms of technologies to be funded and markets to be targeted. The results of the projects on financing, increasing efficiency, reducing CO2 emissions and the dialogue with industrial stakeholders have shown that the investment on the part of the ship owners can be profitable. From the interviews, it was clear that the market is changing, and in the meantime, ship owners are seeing the benefits and the need for new technological solutions and materials on board ships and are also demanding them. One interviewee expressed the following view:

"And indeed, the market is changing where in the past ship owners, they were just always saying no, it's economically already very hard for us, so all changes are more expensive, so we won't change. We are the most energy-efficient transport mode, so we don't have to change. I mean, they were just heading the ground, didn't want to face reality, and now it's changing quite rapidly." – Thematic expert

In this context, the companies also see the environmental friendliness of the ships as a commercial advantage. However, this applies mainly to large ship owners. Smaller ship owners, of which there are many in Europe, are often unable to keep up with the large companies. Furthermore, it became clear from the interviews that projects that go from design to implementation represent a high risk for the commercial partners because, naturally, some challenges can arise in the course of development, and it is difficult to estimate at the beginning whether the final product will be financially viable when it is delivered. In addition, it became apparent from the interviews that a solid infrastructure must be created in the future so that the ports in Europe can accommodate and supply innovative ships. In the E-Ferry project, for example, infrastructure has already been created along the ferry's respective route to make the electric ferry commercially operational. Furthermore, the training of skilled workers for the construction of such innovative vessels must be considered, which is crucial for diffusion and final success on the market.

Despite the fact that commercialization is still limited, environmentally friendly ships are recognized as a new competitive advantage, also due to existing environmental regulations and incentives. However, it is necessary to change the regulatory framework by creating guidelines and regulations to accelerate the market uptake of very low-emission and lightweight vessels. In this context, it is also important that regulatory bodies such as the IMO and flag states are involved in this process.

Technology and Innovation Pathway

All IA projects analysed in this case study focused on the development of technological solutions to reduce emissions from shipping. They dealt with engines, pollution abatement systems, propulsion, energy sources and the introduction of new lightweight and high-performance materials in waterborne applications. The aim was to establish technological solutions for efficiency improvements and emission reductions that go well beyond normal technical progress and to demonstrate the feasibility of virtually emission-free shipping. Another important goal was to ensure that the technological solutions were close enough to market readiness to be considered by end users in the future. In all projects, solutions with a high TRL level (some projects even reached TRL 9) were developed, implemented and validated in a real-scale structure (demonstrator). Prototypes were also incorporated large scale and evaluated in terms of technical characteristics, safety aspects, and economic and environmental impact. The projects primarily targeted the following three areas:

- Lightweight and composite materials for structural components of vessels (FIRBRESHIP and RAMSSES)
- Power and propulsion technologies for increasing energy efficiency and reducing CO2 emissions from ships (LeanShips and HERCULES-2)
- Fuels and alternative energy sources for the decarbonization of shipping (E-Ferry)

Lightweight and composite materials

In the two projects focusing on lightweight and composite materials, several advances were made that go beyond the state of the art of composite materials. The use of lightweight materials instead of the traditional heavier materials, such as steel, has the advantage of reducing the overall fuel consumption of the ship, leading to a reduction in greenhouse gas emissions. The analysis of the projects and the interviews with project beneficiaries showed that there is great potential in the use of lightweight and composite materials for ships. A variety of different materials and solutions (e.g., fibre-reinforced polymers, lightweight rudder flap) were investigated in the projects and, as in the RAMSSES project, 13 demonstrators were developed. The results were very diverse and had to be assessed case by case in terms of market acceptance. In particular, in cases where the starting point was a lower TRL level, further knowledge building and testing are still needed to achieve implementation, as international regulations need to be revised to equip vessels with the new materials (in particular Fibre-Reinforced Polymers).

Overall, however, the projects have shown that the use of new materials can be more attractive than traditional steel versions of ships, opening up an interesting market for European actors in the maritime sector. The advantages that arise are, for example, a reduction in fuel consumption and, thus, a reduction in costs for ship operators. In addition, the ships emit fewer greenhouse gas emissions and underwater noise is reduced due to the higher damping properties of composite materials.

Power and propulsion technologies

The ships currently in use are almost entirely powered by diesel engines. The further development of such powerful engines is, therefore, a very important task. The central issues here are to ensure low fuel consumption and to reduce pollutant emissions. The projects, which focused in particular on power and propulsion technologies, have shown that fuel consumption can be reduced by various propulsion concepts. The main impact of the projects dealing with power and propulsion technologies has been to achieve efficiency improvements and significant emission reductions that go beyond existing legislation and the current best available technology. The HERCULES-2 project achieved efficient engine operation, including low-speed steam operation, through advanced combustion, novel materials, and improved control systems, resulting in drastic reductions in greenhouse gas emissions. Furthermore, the combination of integrated after treatment equipment and control systems achieved the targeted 80% reduction in gas and particulate emissions. The LeanShips project showed with 8 demonstrators how the technologies and ideas developed in previous research projects such as BESST, JOULES, and GRIP could be applied to the real needs of users, as well as demonstrating the economic benefits of adopting such technologies. Demonstrators included, for example, the use of methanol as an alternative fuel, extending the use of energy-saving devices to ships with controllable pitch propellers, and a holistic approach to reducing emissions from passenger ships. The LeanShips project achieved, for example, valuable fuel savings for ships with controllable pitch propellers (CPPs). Nevertheless, there were challenges as well. Because many of the demonstrators were very close to the market, they were highly vulnerable to market fluctuations. The results of the two projects should nonetheless further accelerate the shipping industry's transition to greater fuel efficiency and a significantly smaller environmental footprint.

Fuels and alternative energy sources

The E-Ferry project dealt with the design, development and demonstration of an all-electric battery-powered ferry. The E-ferry is based on a newly developed, energy-efficient design concept, including an optimised hull and propulsion system, a high-energy battery pack, and the use of weight-reducing modules and components. The technology was demonstrated in full-scale operation over greater distances than any previous electric ferries. Project results from the newly built ferry, which can travel distances of more than 20 nautical miles between charges, show that the energy efficiency of the entire electrical system is 85%, twice the efficiency of a typical diesel ferry. Reductions of greenhouse gases and other pollutants were also significant but depended on the extent to which E-Ferry uses 'green' electricity, i.e., electricity produced by clean, renewable sources such as wind and sun. The ferry has a low average energy consumption per trip, in combination with an available battery capacity of more than 3.8 MWh and a fast charger, which proves that the E-ferry prototype is a valid commercial alternative to traditional diesel- and diesel-electric-propelled ferries. An important advantage was that the E-Ferry project was able to learn from previous projects where the main specifications etc., had already been designed and could therefore start with a higher TRL.

The goals of the project were finally achieved. It was to prove the concept by developing, building and demonstrating a fully operating E-ferry prototype – moving the E-ferry TRL-level from 5 up to 9 during the project duration, significantly increasing the electrification of waterborne transport in Europe through market uptake of the E-ferry concept across European ferry operators both in coastal operation and on inland waterways.

8.4. Conclusion

E.Q 4.1. What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results all together leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

Overall, the projects analysed have made a significant contribution to the H2020 measures to reduce pollutant and greenhouse gas emissions from shipping. The projects have delivered a wide range of new technological and material solutions, providing important findings for the transition to very- low-emission and lightweight vessels. All analysed projects have successfully developed prototypes and shipboard demonstrators to demonstrate the feasibility of near-zero emissions shipping, thereby contributing to the objectives of the Framework program. While there does not appear to be a single measure that can be considered a problem solver, the combination of solutions such as new propulsion systems, new fuel types, and lightweight materials should result in significant energy efficiency improvements and environmental benefits. It would be, therefore, helpful to have some calls in the future where these solutions can be combined within a single project.

"I think if I could add something to my wish list, I would like to see some projects where we can combine solutions like that, like new propulsion systems, new types of fuel and lightweight. This is something because I think there are several enablers for reduction of emissions which combination could really lead to some spectacular achievements."- Project Beneficiary

Another key objective of the framework program was to develop solutions that are so close to market readiness that ship owners will consider these concepts in their future investments. All projects succeeded in significantly increasing the TRL, thus making the ships commercially viable with their new technological equipment and materials. In particular, certification procedures established in the E-Ferry project, for instance, can now be adapted, thus saving time and money and facilitating the introduction of new vessels. However, in some cases, it became apparent that further steps need to be taken to make certain technologies or materials marketable. In particular, it should be noted that a future demo case starting at a low TRL level will require more time for knowledge development to ensure practical implementation and to actually make the prototypes marketable. Some interviewees, therefore, emphasized the need for more knowledge-building with EU funding in smaller projects focused on a single problem first before integrating it later into the whole system on higher TRL. Demonstrations that are conducted off-shore and start at a lower TRL are also very cost- and risk-intensive, so shipyards or ship owners do not like to venture into demonstration projects that much unless the ships can be sold afterwards. To minimize risks for ship owners or other commercial users, the greening of ships should be even more focused on these commercial stakeholder groups and their needs. The uptake and interest of commercial stakeholders would also increase if there were new rules and regulations from the policy side. Therefore, new regulations would be urgently needed to achieve the goal of near-zero emissions shipping and to guarantee the acceptance to invest in new (technological) solutions and materials on board ships. In addition, due to the high complexity of the shipping sector, it is important that extensions are granted during the project period in order to find solutions to challenges and the minimization of risks. To make the ships really marketable and operate them in real life, an infrastructure in ports is also necessary, which must be established.

E.Q 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact?

In this case study, several success factors were identified that had a particular influence on the progress of the Framework Program interventions. In the following, the main success factors are briefly explained:

Project consortium and partners involved

A key success factor for all projects was that they had a heterogeneous consortium with industry partners such as shipyards or technology providers. It is important to work with commercial partners in the project right from the start so that the knowledge built up in the projects is more likely to be used in practice and lead to the acceptance and uptake of environmentally friendly vessels. Based on some interviews with project beneficiaries, it was furthermore helpful to split the role of the project coordinator between two organizations to increase the efficiency of the project work.

Cooperation with other EU projects

Cooperation with other EU projects aiming at similar solutions and facing similar challenges proved to be particularly valuable for the success of some projects.

Technology transfer

The aspect of technology transfer, e.g., from the aerospace industry, to learn from and adopt know-how, was seen as very fruitful.

Use of knowledge from previous projects

Using and building on knowledge from previous (EU) projects in the maritime field was crucial for all analysed projects to move forward faster in their own respective projects.

Support from the EC

The support provided by the European Commission, and in particular by the project officers, was a factor contributing to the success of most of the analysed projects. Since the shipping sector is highly complex, major challenges can always arise, which then cause delays in the progress of the project. A project officer who understands this complexity and supports the project beneficiaries is, therefore, essential.

Higher TRL right from the very beginning to ensure a successful market entry

Currently, there is a large amount of technology push, along with a shift in market demand in the shipping sector. The decarbonization targets are more and more noticed in the market, where ship owners are beginning to invest in innovative technologies. In order to attract ship owners to projects, it can sometimes be important that a commercial benefit is evident, as well as that the results of the projects are close to or ready for market uptake. From the analysis, it was found that a higher TRL at the very beginning of the project is quite often essential to ensure market readiness at the end of the project's lifetime.

In terms of potential obstacles, the following area stood out:

Regulation and Standards

The traditional way of building ships is still based on existing (international) regulations that need to be changed in order to commercially exploit the low-carbon and more energy-efficient ships and their technologies or materials. There are currently only preliminary new guidelines in place, which require further feedback from the international community before new regulations can be adopted. Certain markets, such as the ferry market, are changing faster than, for example, the cargo ship sector. In the ferry sector, the shift to electric and environmentally friendly operations is very much underway. However, governments often have an influence here, as ferry operators are part of the public transport sector. It becomes clear in this respect that politics strongly influences sustainable shipping efforts. In future projects, therefore, a combination of research and the development of requirements for standards or certification measures would be helpful. In this regard, it is also key that standard & certification organizations are involved in projects from the very beginning. Such organisations do not necessarily need to be involved as funded project partners but as important network partners during the life of the project. In this way, the process of setting new standards, which follow its own rules and must take place outside the individual projects, can be accelerated and made more effective on the basis of the knowledge base developed and the requirements arising from such R&D projects.

E.Q. 4.3: To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts?

To demonstrate the benefits of the new vessels and/or their innovative technologies or materials and to foster their application, a vast number of dissemination activities have been carried out in the context of the projects. This includes scientific publications, the organization of events, the production of video material and the use of many other communication formats such as social media. Conferences and final events were very important for all respondents to communicate and disseminate their outcomes. However, COVID-19 negatively impacted some of these important communication and dissemination efforts. Many conferences had to be held online and could not be organised as large as originally planned. Cooperation in communication and dissemination activities with relevant networks such as the “ELAS network”, “The EU Resource Efficiency Transition Platform” or the “Sustainable Shipping Technologies Forum” are highlighted as particularly valuable. Within those networks or platforms, public events can be organized, which in turn attract a lot of attention and reach broad stakeholder groups.

Project websites were also considered important to communicate and disseminate project outcomes. However, it was seen as a challenge to keep the project website alive after the end of the project period. In order to maintain the knowledge repository for the community, funding or a platform would have to be provided even after the project duration in order not to lose the knowledge and to make it easily accessible. One interviewee noted that current sites such as CORDIS are a little complex, especially for industry stakeholders, and that they often do not have the time to click through. This is why dedicated platforms are so important so that stakeholders from the industry, in particular can obtain information.

EQ 5.1: What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed? Could the stakeholders have implemented their research and innovation in another way, including through other national or regional support?

Funding opportunities for the development of very-low-emission and lightweight vessels vary widely among member states. Most of the analysed projects could not have been realised with national funding due to their size, high TRL and budget. In particular, the building of demonstrators is very difficult to realise with national funds. EU projects also enabled beneficiaries to come into contact with companies or research organizations that would never have happened without the funding via the framework program. These collaborations inspire and stimulate new ways of thinking by opening up discussions with a wide range of partners from different countries. In addition, EU projects offer the opportunity to gain a very broad spectrum of experience and to expand one's network.

8.5. Annexes

8.5.1. Key metadata of case study no. 8 Very-low emission and lightweight vessels

Table 75. Key metadata of case study no. 8 – Very-low emission and lightweight vessels.

Case no. 8	**Very-low emission and lightweight vessels**
Evaluation Question addressed*	EQ 4.1, 4.2.; 4.3; 5.1.
Area	Sustainable Transport
Programme parts	WP 2014/2015 (Smart, Green and integrated Transport) WP 2016/2017 (Smart, Green and integrated Transport)
Scope	2 Horizon 2020 calls Time horizon covered: 2014 – 2020. Number and type of instruments analyzed: 5 IAs Number of projects analysed: 5
Key data sources	H2020 Work Programs & relevant call text Project data from CORDIS & CORDA 6 interviewed persons (1 Expert, 5 Project Beneficiaries) Strategic Policy Documents (Strategic goals and recommendations for the EU’s maritime transport policy until 2018, Transport White Paper, Implementation of the EU Maritime Transport Strategy 2009-2018, Mobility Strategy)
Links with partnerships	n/a
Relevant policies	Strategic goals and recommendations for the EU’s maritime transport policy until 2018, 2009 EU Transport White Paper, 2011 Mobility Strategy, 2020 Implementation of the EU Maritime Transport Strategy 2009-2018, 2016

Table 76. Project information.

Project Acronym	Project Call ID	Topic	Action Type	EC Net Contribution (Euro)	Project Start	Project End
HERCULES-2	H2020-MG-2014_TwoStages	MG-4.1-2014	IA	16 813 399,63	01.05.2015	31.10.2018
LeanShips	H2020-MG-2014_TwoStages	MG-4.1-2014	IA	15 752 357,97	01.05.2015	30.04.2019
E-ferry	H2020-MG-2014_TwoStages	MG-4.1-2014	IA	15 141 035,88	01.06.2015	31.05.2020
RAMSSES	H2020-MG-2016-Two-Stages	MG-2.2-2016	IA	10 799 440,65	01.06.2017	30.11.2021
FIBRESHIP	H2020-MG-2016-Two-Stages	MG-2.2-2016	IA	8 866 322,75	01.06.2017	31.05.2020

8.5.2. Table of Horizon 2020 calls analysed

Table 77. H2020 calls analysed.

WP 2014/2015 (Smart, Green and integrated Transport)	MG-4.1-2014 - Towards the energy efficient and emission free vessel
WP 2016/2017 (Smart, Green and integrated Transport)	MG-2.2-2016 - Development, production and use of high performance and lightweight materials for vessels and equipment

9. Case study 9: Zero emission aircraft

9.1. Summary

The case study identifies and analyses relevant actions related to zero emission aircraft in Horizon 2020. The thematic scope of the case study comprises technological innovations on aircraft by developing new types of vehicles, propulsion concepts or materials used to assess whether the research has led to breakthrough innovations towards zero emission aircraft.

Projects in the portfolio were able to generate significant improvements in performance as well as increase the maturity of the involved technologies. Some of the projects can be considered pioneering and demonstrate the potential of, for instance, electric aviation and hydrogen in aviation. Projects have also contributed to the development of new materials. Altogether, the projects' results are therefore leading to the achievement of the programme's objectives in this area. Objectives did not address zero emission explicitly but were directed at breakthrough innovations and a significant reduction of energy consumption. With the Green Deal, the EU has contributed to a notable shift in priorities towards more sustainability.

We identified four enabling factors for the effectiveness of the portfolio, 1) building on previous project results, 2) bringing excellence together, 3) integration of partners from other industries and 4) working closely with regulatory authorities. There are also barriers to achieving impact: 1) small budgets, 2) aviation as a conservative industry, 3) original equipment manufacturers (OEM) being risk averse and 4) fewer Scientific Officers at the Commission. The most important added value generated is that for some of the participants, research would not have been possible at all in the lack of national funding programmes dedicated to research in the field of aviation.

9.2. Introduction and overview

9.2.1. Objectives

To contribute to the green transition and in line with the Sustainable and Smart Mobility Strategy (2020)[1], all transport modes need to become more sustainable as all are indispensable for our interconnected transport system. As there is no proven solution for a zero-emission aircraft yet research is needed to advance technological innovations in the engine and structure of the aircraft to reduce greenhouse gas emissions and noise. Action needs to be taken now as the rise in air travel traffic is expected to outpace the gains made in reducing aircraft emissions through efficiency measures and technological advances over the next 20–30 years. With around 10 years to design and get certification for a new aircraft and aircrafts being in use for 20 to 30 years, an evolutionary approach only will not be sufficient to meet ambitious targets, but new, disrupting innovations are needed.

The case study identifies and analyses relevant actions related to zero emission aircraft in Horizon 2020. It looks at technological innovations in aircraft by developing new types of vehicles, propulsion concepts or materials used. It assesses the implementation of the Horizon 2020 funded projects in this area and how the results and outcomes contribute to the overarching goals of Horizon 2020. Against this background, the main objective of this case study is to analyse to which extent Horizon 2020 actions enabled ground-breaking innovations that can contribute to zero emission aviation that can be further scaled up in Horizon Europe. It will do this by analysing the Logic Model set out in the main report by outcome pathway and provide responses to the relevant evaluation questions. However, it has to be noted that this case study is based on a small number of projects, and the analysis is of a qualitative nature. While robust in approach, it can only refer to the projects included.

9.2.2. Methodology and case study structure

The analytical approach commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to Sustainable Transport and Mobility (e.g., Transport White Paper 2011, Sustainable And Smart Mobility Strategy Putting European transport on track for the future, 2021). This led to the identification of four areas of interest for the Green Transition: a) More sustainable modes of transport, b) More sustainable alternatives (supply side), c) More sustainable choices (demand side), and d) Reducing pollution and risk. The case study Zero Emission Aircraft is part of the case studies covering area a).

The case study approach includes a literature review to gain a better understanding of the case study topic as well as an overview of the project portfolio in the area by project data. The analysis comprised 3 Horizon 2020 calls. The time horizon covered with the analysis is 2014 – 2022. The type of instruments analyzed are RIAs only. An overview is provided in the Annex of this case study.

For the identified projects, relevant data (as available from Cordis/eCorda data) has been compiled and analysed, including budget, number of project participants, geographic origin and types of beneficiaries, project type, and project results. For the most relevant actions, this has been complemented by further information from additional sources like project websites.

7 in-depth interviews were carried out with experts with academic backgrounds as professors in aeronautics, aeronautical engineering, aircraft instrumentation and avionics, hybrid-electric propulsion systems, having leading positions in aerospace corporations and being members of national and European Scientific Advisory Boards, beneficiaries of H2020 and representatives of the Commission. The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus.

For synthesizing the analysis, we triangulated and analyzed the findings in relation to the evaluation questions using the impact pathways as described in the logic model presented in the main report (see Figure 5 for the expected outcomes).

9.3. Synthesis of evidence

9.3.1. Innovative technologies to reduce aviation emissions

All transport modes need to become more sustainable to achieve the overall goal of delivering no net emissions of GHG by 2050. Aviation accounts for between 2 and 3% of CO_2 emissions globally and 4% in Europe. When non-CO_2 emissions are taken into account for all sectors, then this proportion might increase significantly.[2] Even though the share of aviation is comparatively small in relation to other sectors, a key challenge is that it is particularly hard to decarbonize.

For aviation, there are different routes to reducing climate-damaging emissions, which fall into four main categories: a. technological innovations on the engine and structure of the aircraft, b. optimizing airspace management and ground operations, c. the use of low-carbon power, including alternative fuels, d. market-based measures like compensation.[3]

Within this case study, the focus lies on technological innovations in aircraft that support a reduction of CO2 and NOx emissions as well as a decrease in particulate matter. While improvement of the environmental impact of the aircraft can be achieved, for instance, through better engine efficiency and advanced combustion technologies, improved aerodynamics or reduction of the weight of an aircraft, breakthrough innovations are also needed to achieve zero-emission aircraft.

Significant advances have been made in the last ten years in a number of areas that aviation research can now benefit from. Advances have been made in fuel cell technologies as a possible alternative energy source which around ten years ago would not have been thought possible, with more than 100 research groups worldwide working on this subject at present. European Research has clearly contributed to this development. Advances have also been made in electric motors, with development having greatly benefitted from research conducted by the automotive industry, with the introduction of Formula E, among others. Aviation research can learn from the technological development in this industry. Other interesting areas are very large electric motors that have been used in locomotives, ships and submarines and lightweight construction, which has also greatly advanced and benefitted from European funding.

Going forward, there are different research areas that are being pursued. Short-range electric aircraft for commuting and travelling, surveillance, working and leisure/recreation are being developed.[4] These will be small battery-powered aircraft with up to seven seats that will be able to fly with zero emissions on short distances. The main challenge with battery-powered aircraft is the range which is only around 100 to 200km at the moment.

Batteries cannot be scaled-up for use in larger aircraft because their energy density is not sufficient. Hydrogen-powered fuel cells have received great attention in on-going research in this area. For larger aircraft, liquid hydrogen is preferred to pressurized hydrogen due to its higher energy density. Because it is still much lower than kerosene, the high hydrogen volume must be managed by new aircraft configurations.[5] There remain challenges around the integration and positioning of the tank and the integration of electrified drives within the aircraft.

Other challenges include infrastructure decisions that need to be taken regarding, for example, storage facilities of alternative fuels or hydrogen and also airport layout if aircraft configuration were to change more radically.

9.3.2. Strategic policy priorities related to zero-emission aircraft

At the inception of Horizon 2020, the main priorities in aviation research lay around growth and competitiveness. Environmental considerations were also being made, with sustainable aviation fuels as a priority.[6] Striving for zero emission aircraft was not yet on the agenda.

Tasked by the European Commissioner for Research, the Advisory Council for Aviation Research and Innovation in Europe (ACARE) developed the first European sector-wide vision, “European Aeronautics: A vision for 2020: Meeting society’s needs and winning global leadership”, in 2001. This vision already formulated clear goals on the sector’s contribution to a sustainable environment with reduction targets of a 50% cut in CO_2 emissions per passenger kilometre and an 80% cut in nitrogen oxide emissions as well as noise reductions. This was followed in 2011 by “Flightpath 2050 Europe’s Vision for Aviation: Report of the High-Level Group on Aviation Research”. Goals for 2050 included a 75% reduction in CO_2 emissions per passenger kilometre, a 90% reduction in NOx emissions and perceived noise emission reduction of flying aircraft by 65%[7]. Emission-free aircraft were aspired for movements in taxiing.

The Commission’s Aviation Strategy for Europe[8] from 2015 mainly focused on growth and competitiveness. While it is acknowledged that EU action is needed to contribute to a resilient Energy Union and a forward-looking Climate Change Policy, no specific actions from the Commission are noted in the strategy for this area.

A notable shift came with the declaration of the Green Deal (2019)[9]. The consecutive Mobility Strategy (2020)[10] emphasizes that “By far, the most serious challenge facing the transport sector is to significantly reduce its emissions and become more sustainable.” (p. 1). It acknowledges the decarbonization challenges of air and waterborne transport, resulting in a need for priority access to sustainable fuels. "Significant efforts are also needed to develop disruptive technologies to bring zero-emission vessels and aircraft to the market. The Union should create the enabling environment to achieve this, including through adequate carbon pricing policies and research and innovation (R&I), in particular through the partnerships that could be put in place under Horizon Europe (such as 'Zero Emission Waterborne Transport', 'Clean Aviation' and 'Clean Hydrogen')." (p. 5)

With the Destination 2050 initiative and roadmap, five leading European aviation associations came together to show a decarbonisation pathway for European aviation with the objective of reaching net zero CO_2 emissions by 2050 from all flights within and departing from the EU, among others.[11]

The latest ACARE report (2022) is titled "Fly the Green Deal" and also pledges to achieve climate neutrality in Europe: "By 2050, Europe's world-leading research and innovation has delivered advancements in zero emission and clean energy sources that means all European journeys are climate neutral. Local air quality is assured. Noise and other nuisance impacts are minimal."[12]

In June 2022, the Alliance for Zero-Emission Aviation was launched by the Commissioner for Internal Market with the aim of preparing the market for the entry into service of zero-emission aircraft addressing aspects of fuel and infrastructure requirements at airports, sourcing of renewable fuels and electricity, standardisation and certification, as well as practices for airlines and air traffic management.[13]

9.3.3. Horizon 2020 programming related to the case study topic

The specific challenges set out in the work programmes 2014/2015 as well as 2016/2017 (Smart green and integrated transport), as well as the expected impact of the relevant calls, are reproduced in the following table. Horizon 2020 R&I topics in these calls are ahead of the Aviation strategy at the time but are following the Strategic Research and Innovation Agenda (SRIA) of the Advisory Council for Aviation Research and Innovation in Europe (ACARE) that has been developed following the "Flightpath 2050 Europe's Vision for Aviation". The calls do not aim at zero emission aircraft but at breakthrough innovations; one call makes it explicit not to assume fundamental changes at the airport level.

Table 78. Specific challenges and expected impact of H2020 calls covered in case study.

H2020 call	Specific Challenge	Expected Impact
MG.1.5-2014 Breakthrough innovation for European aviation[14]	"A number of very ambitious goals have been set by the sector at horizon 2050 in the Strategic Research and Innovation Agenda (SRIA) of the Advisory Council for Aviation Research and Innovation in Europe (ACARE). Many of these goals will not be reached through an evolutionary approach only. Breakthrough innovations are needed, i.e. new solutions which rely on a disruption with respect to current approaches."	"Actions will demonstrate their potential to mature the Technology Readiness Level (TRL) in the range 1-2, to prepare the ground for future highly innovative breakthrough products and services for European aviation which will contribute to decrease the environmental impact, enhance the competitiveness, the mobility and the levels of safety. Actions will also provide ad-hoc indicators to evaluate the potential improvements that the breakthrough technology / concept is capable of bringing, using realistic hypothesis and scenarios."
MG-1.1-2016 Reducing energy consumption and environmental impact of aviation[15]	"The reduction of energy consumption in aviation leads to high social, environmental and economic benefits and will ensure its sustainability. It leads to improved resource efficiency, reduction of CO2 and NOx emissions as well as decrease of the particulate matter. If no actions would be undertaken, the adverse impact of aviation on environment would significantly grow due to the expected increase of air transport traffic by 5% every year. Improvement of the environmental impact of the aircraft can be achieved for instance through better engine efficiency and advanced combustion technologies, improved	"As mentioned in the specific challenge, reduction of energy consumption leads to improved resource efficiency, reduction of CO2 and NOx emissions as well as decrease of the particulate matter. Actions will contribute towards greening the aviation through increased energy efficiency of the aircraft and wider use of alternative fuels. They will mature technologies capable of: —Bringing measurable reduction of environmental impact towards the long-term goals of reducing CO2 by 75% and NOx by 90% (per passenger and per kilometer) by 2050 (baseline year 2000). —Facilitating the introduction of alternative fuels in aviation towards the

	aerodynamics or reduction of the weight of an aircraft.”	long-term goal of 40% biofuels share in aviation fuels by 2050.”
MG-1-4-2016-2017 Breakthrough innovation (end 2020/21/22)[16]	“Very ambitious long-term goals are addressed by Europe's vision for aviation Flightpath 2050, in particular for maintaining and extending industrial leadership and for protecting the environment. As many evolutionary technologies are mature near to their maximum potential, new disruptive breakthrough technologies are needed to reach these ambitious goals.”	“Actions will propose new or develop further highly innovative and exploitable breakthrough technologies for the medium term that will make feasible a substantial decrease of the impact on climate and the environment of air vehicles and/or enhance the competitiveness of the European aviation industry and the safety of civil aviation. They should demonstrate the proof of concept and consider integration issues without assuming fundamental changes at airport level. Proposals are also expected to demonstrate the validity of the technologies and concepts following a sound technical and scientific approach as well as significant decrease in the environmental impact and/or high potential for new market opportunities for the European aviation industry.”

The portfolio of projects covered in this case study comprises 14 different projects, with 122 participations and EU contributions of 60.7 Mio €. The instrument type is Research and Innovation Action. An overview of the projects in question is provided in the annex.

9.3.4. Project portfolio characteristics

The project portfolio of this case study comprises 14 projects spanning a time frame, with the earliest project starting in April 2015 end the latest ending in March 2022. The sum of EC's net contribution is EUR 60.7 Mio. Compared with the net contribution within SC4, the share is 1% and hence only covers a very small part of the overall funding for transport and mobility.

Table 79. Type of organisations in case study Zero Emission Aircraft.

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1000)
		Nb	Share (%)	EUR (1000)	Share (%)	
HES	12	41	34%	21,785	36%	531.3
OTH	0	0	0%	0	0%	N/A
PRC	11	54	45%	24,907	41%	461.2
PUB	0	0	0%	0	0%	N/A
REC	11	26	21%	13,992	23%	538.2
Total (All types)	**14**	**121**	**100%**	**60,684**	**100%**	**501.5**

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

Source: eCorda, own calculation.

A share of 41% of EC's net contribution has been allocated to private companies, 36% to higher education institutions and 23% to research organisations. Compared with all other Green Transition areas considered in this study (SC2 to SC5), the project portfolio of Zero Emission Aircraft has the highest share of higher education institutions (36% in the case study vs 19% in all Green Transition areas), indicating a particularly high need for basic research which is in line with the focus on ground-breaking innovations.

Table 80. Type of actions/instruments (grouped) in case study Zero Emission Aircraft.

Group of Action/Instrument	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)
IA	0	0	0.0%	0.0	0.0%	N/A
RIA	14	121	100.0%	60,683.6	100.0%	501.5
CSA	0	0	0.0%	0.0	0.0%	N/A
SME	0	0	0.0%	0.0	0.0%	N/A
Other	0	0	0.0%	0.0	0.0%	N/A
All types	**14**	**121**	**100.0%**	**60,683.6**	**100.0%**	**501.5**

Source: eCorda, own calculation.

With the whole amount of funding allocated to Research and Innovation Actions (RIA), the case study portfolio is characterised by a high degree of basic research compared with the aggregated Green Transition project portfolio, in which the share of RIA is at 47.3%. The portfolio highlights commitment to groundbreaking research at rather low Technology Readiness Levels.

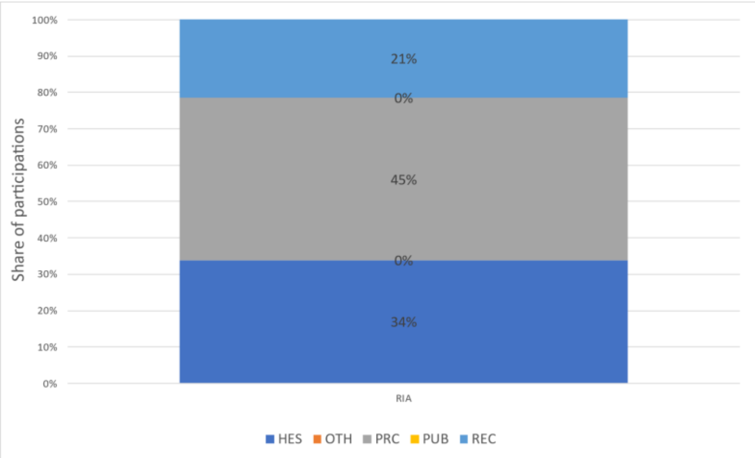

Figure 237 Share (%) of participations by type of action/instruments.

Source: eCorda, own calculation.

Geographically, the eCorda statistics show that Horizon 2020 is mainly concentrated on EU-14 countries plus the UK. Around 90 % of the participation, as well as the EC contribution, are shared among this group. EU-13 countries have slightly less participation than the UK (8.3 % compared to 9.9%), with a nearly equal share of EC contribution (10.9 % and 10.5 %). Participation from other countries is an exemption. Only one associated country (Switzerland) and one-third country (Russia) are represented, with a share of only 0.5 % of the EU contributions.

Table 81. Group of countries of the case study Zero Emission Aircraft.

Group of country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Number of countries
H2020-EU27	14	107	88.4%	53,995	89.0%	504.6	17
EU-14	*14*	*97*	*80.2%*	*47,360*	*78.0%*	*488.2*	*12*
EU-13	*6*	*10*	*8.3%*	*6,635*	*10.9%*	*663.5*	*5*
H2020-associated (exclude UK)	1	1	0.8%	331	0.5%	331.3	1
United Kingdom	8	12	9.9%	6,357	10.5%	529.8	1
Third Countries	1	1	0.8%	0	0.0%	0.0	1
All-countries	**14**	**121**	**100.0%**	**60,684**	**100.0%**	**501.5**	**20**

Source: eCorda, own calculation.

In terms of participation pattern, Germany stands out with the highest share of participation (26%) and EC contribution in total funding (27%). France, Italy and the UK follow with shares of participation at 14%, 11% and 10% and shares of funding at 10%, 15% and 10% respectively. All other countries' participation shares are in the single digits with respect to participation and funding.

Table 82. Top countries (of supported organisations) in Case Study Zero Emission Aircraft.

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Order
		Nb	Share (%)	EUR (1,000)	Share (%)		
Germany	12	32	26.4%	16,124	27%	503.9	1
France	9	17	14.0%	6,065	10%	356.8	2
Italy	9	13	10.7%	8,920	15%	686.1	3
United Kingdom	8	12	9.9%	6,357	10%	529.8	4
Netherlands	7	9	7.4%	5,104	8%	567.1	5
Greece	4	6	5.0%	2,320	4%	386.7	6
Spain	4	5	4.1%	2,059	3%	411.7	7
Sweden	4	6	5.0%	1,766	3%	294.3	8
Belgium	3	4	3.3%	1,230	2%	307.6	9
Poland	2	2	1.7%	586	1%	293.1	10
Denmark	1	1	0.8%	795	1%	795.4	11
Portugal	1	2	1.7%	1,049	2%	524.3	12
Russia	1	1	0.8%	0	0%	0.0	13
Switzerland	1	1	0.8%	331	1%	331.3	14
Ireland	1	1	0.8%	629	1%	628.6	15
Austria	1	1	0.8%	1,300	2%	1,299.8	16
Hungary	1	2	1.7%	1,177	2%	588.7	17
Slovakia	1	1	0.8%	286	0%	286.2	18
Slovenia	1	3	2.5%	3,764	6%	1,254.6	19
Czechia	1	2	1.7%	821	1%	410.7	20

Source: eCorda, own calculation.

The network analysis based on the number of collaborations among organisations from each pair of countries in the projects included in this case study confirms that the three founding countries of Airbus – France, Germany and the UK – are still at the core of collaboration, with the Netherlands and Italy being important partners.

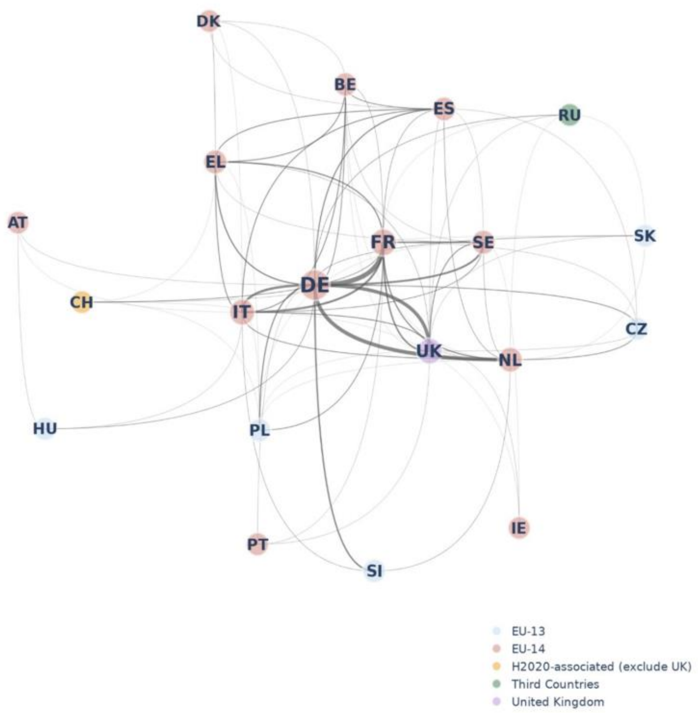

Figure 238 Network of participating countries in the case study Zero Emission Aircraft.

Source: eCorda, own calculation.

9.3.4.1. European Partnerships related to Zero Emission Aircraft

In addition to the Horizon 2020 project portfolio and its related calls, the public-private partnership Clean Sky 2 constitutes a relevant part of actions co-funded by the European Union.

Because this evaluation study will also assess partnerships active in Green Transition-related fields with a legal obligation for evaluation, there will be a separate case study on Clean Sky 2. The case study, therefore, does not contain projects funded by this partnership.

Clean Sky 2 was established with the objective "to contribute to improving the environmental impact of aeronautical technologies, including those relating to small aviation, as well as to developing a strong and globally competitive aeronautical industry and supply chain in Europe. This can be realised through speeding up the development of cleaner air transport technologies for the earliest possible deployment and, in particular, the integration, demonstration and validation of technologies capable of (i) increasing aircraft fuel efficiency, thus reducing CO_2 emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014; (ii) reducing aircraft NOx and noise emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014."[17] The sum of EC's net contribution to Clean Sky 2 is EUR 1,6 billion, which represents a share of 28 % of the sum of EC's net contribution to SC 4.

In line with this financial size, the interviews clearly indicated that Clean Sky 2 plays an important role for the European aviation research community and is often referred to by the interviewees.

9.3.4.2. Results of the Horizon 2020 funding activities: pathways to impact

Already Horizon 2020 and its Work Programmes aimed to contribute to a green transition. The analysis of the Work Programmes and the projects showed that distinct pathways to impact can be identified that connect the activities carried out within the work programme with identifiable effects (outcomes). Based upon the Work Programme analysis, Figure 1 provides an overview of pathways to impact identified in the analysis regarding transport and mobility.

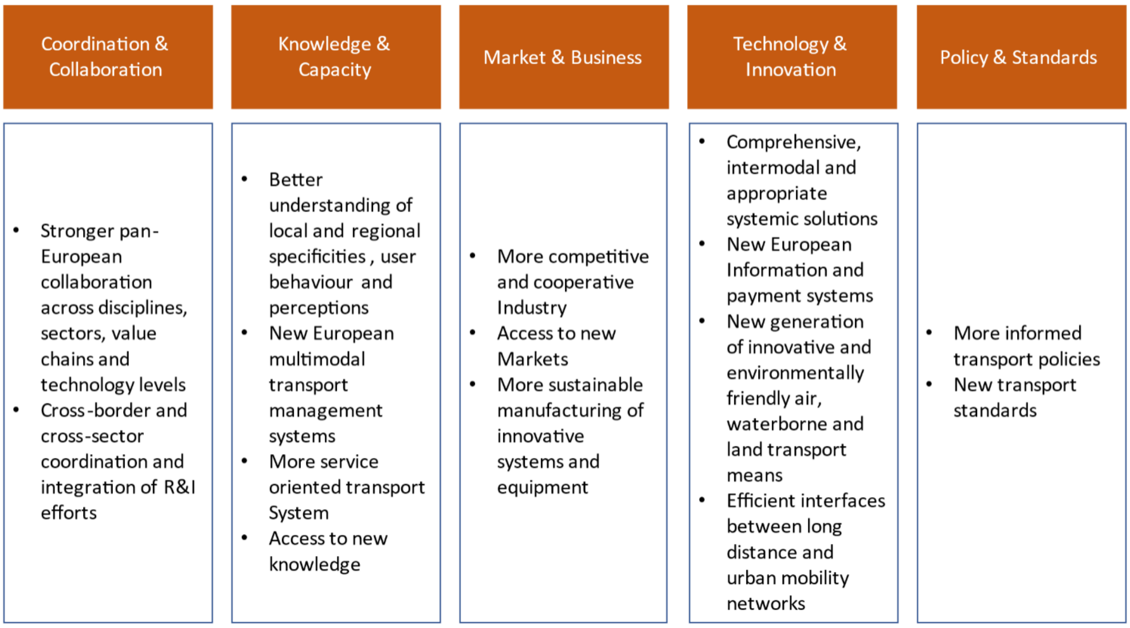

Figure 239 Expected Outcomes across all analysed calls.

9.3.4.3. Coordination & Collaboration Pathway

Coordination and collaboration between different countries and network building within the aviation research community played a considerable role in the portfolio.

The aviation community is rather small, with everybody knowing everybody else. EU programmes are open to collaboration between research partners from non-traditional core aviation countries like, for example, Poland (Aviation Valley) or Slovenia. The projects brought together players that previously had not been working together, especially from those countries that do not have a strong aviation base, giving them access to the aviation community.

Developing a new technology like electric or hybrid aircraft components is facilitated by bringing in new partners from other disciplines and industries. Cooperation with actors from other industries (specific cases include the automotive industry for electric motors) was supported. Interviewees pointed out that it is necessary to build on the knowledge from other sectors to make progress in aviation. Previous experience in neighbouring fields helped to find partners for cooperation.

"The more complementary consortium or knowledge you have, the better, because it is impossible to think that the normal, or let's say, the classical players in the world, will change aviation itself. Because we will need knowledge from different areas if we really want to change something. Otherwise, everything will be slower, and probably solutions will be less optimized because we have to learn from the other environments." – Beneficiary

Challenges arising from these new technologies will be different and require new forms of cooperation that need to be better aligned and institutionally interlocked than today. With limited resources available, it is important to support a complementary regional development, not competition between regions.

Projects have also allowed access to research infrastructure in other countries. Some countries like Germany have very good test sites and research infrastructure, but these are often used commercially. EU projects help to access testing facilities in other countries that might be better available for research and less expensive. The INCAS Trisonic Wind Tunnel in Romania was mentioned as an example, although it did not participate in one of the projects of this specific case study.

The collaboration extended mostly to partners within the EU, UK and associated countries. International cooperation beyond the EU is dependent on political support, which sometimes changes quickly.

9.3.4.4. Knowledge & Capacity Building Pathway

EU projects are being praised for bringing together researchers and young scientists across Europe, forming a network of researchers in neighbouring fields to tap into for arising questions or to form new research ideas and projects. These networks also allow for an exchange between companies and research institutions, making research more receptive to practical needs and challenges.

Projects give access to talent, helping companies to recruit personnel, thus supporting a direct way of knowledge transfer from research projects into business. In the consortia, the best researchers in a specific domain from different countries come together, also attracting qualified young people at the beginning of their careers. Often these young professionals stay in one of the consortium's companies after they have completed their studies. This is seen as something valuable for the companies because these young people are already acquainted with the company, and they do not need extra onboarding and training.

However, interviewees point out that the training of students and young professionals is not systematic enough yet to fill the foreseeable demand for new technologies like electric aviation and hydrogen. A decrease in the number of aircraft programmes in the last decades meant that young professionals have been exposed to fewer different types and thus have less experience. Serious games – video games that are designed for teaching and training instead of pure entertainment – are mentioned by one interviewee as an example of an innovative way of training for new technologies or new aircraft programmes that could be used.

9.3.4.5. Market & Business Pathway

With the research in this project portfolio predominantly taking place at lower Technology Readiness Levels, the market and business pathway is less important than the other pathways. For take-up of results in the aviation industry, trusted and reliable partners are preferred, partners that have previously established a successful working relationship. OEMs tend to be conservative in this regard, making it difficult for newcomers to enter the market. With the aviation business being international, working on the EU level opens up working with players beyond the national level. Working on research projects also helps to build up relationships which can, at a later stage, be transformed into a business.

One interviewee mentioned an SME for composite materials as a new actor in the market that was able to win contracts with big companies because they were able to showcase their capacities within one project. This helped them to widen their client base.

Another example is the acquisition of a successful SME by an international market leader, which is a sign of the market and business value the company had created. Their participation in the EC-funded project immensely contributed to this.

9.3.4.6. Technology & Innovation Pathway

The technology and innovation pathway is arguably the most important outcome area for this case study, with most of the projects conducting research on low TRL aiming to develop new technological innovations on aircraft by exploring new types of aircraft configurations, propulsion concepts or materials used.

Significant improvements in performance as well as increasing the maturity of the involved technologies, were attributed to the projects. There were projects that, according to interviewees, have been pioneering and demonstrated the potential of, for instance, electric aviation and hydrogen in aviation. Projects have also contributed greatly to the development of new materials. As proof of impact, interviewees refer to their observation that major players are following these developments.

"*We have seen projects that have been pioneering and demonstrated at a certain scale the potential of, for instance, electric aviation, hydrogen in aviation. And one proof of this is that now the major corporations are also trying to follow on, years later, to follow this line and to build upon and to scale it up.*" – Project Officer

Investigated technologies within the portfolio include:

New engine/motor concepts exploring gas turbine engines, contra-rotating open rotor engines, superconducting motors, electric propulsion motors, hybrid propulsion systems using normal combustion engines combined with batteries and fuel cells, and parallel hybrid powertrains.

New aircraft configurations are investigating innovative box-wing aircraft configurations, propulsion-airframe integration approaches, and high-speed aircraft configurations enabling long-haul travels.

New materials like hybrid thermoplastic composite materials, smart-materials, and metamaterials to increase aerodynamic efficiency, reduce production time and cost, introduce self-repair and achieve noise reduction.

To put the results into context, several interviewees pointed out that the projects' budgets are very small compared to investments of large players in research and development in the aviation industry. Because of the scale of the investment, major companies like Airbus are waiting for technologies to mature to a certain degree before they invest in adapting these to their aircraft segment or larger commercial aircraft.

One project has been highlighted by several experts: MAHEPA – Modular Approach to Hybrid Electric Propulsion Architecture. In this project, two variants of a low-emission, high-efficiency, serial-hybrid-electric propulsion architecture have been advanced to TRL 6. The first used a hydrocarbon-fuelled internal combustion engine and an electric generator as the primary power source, while in the second, a hydrogen fuel cell was used to produce power showcasing the flexibility of the architecture. In the project, all-electric take-offs could be proven, significantly reducing noise impact. Other results include improving the performance of the fuel cell and generally increasing the maturity of the technology. Largely attributable to this and preceding EC-funded projects, the coordinator, a Slovenian light aircraft manufacturer, was able to introduce the first fully electric aeroplane worldwide to receive type certification.

"*Even if it is a certain scale – of course, we are not there for larger commercial aircraft – but I think this is already something tangible in terms of results of a project that has been paving the way and showing real impact in what is possible to achieve. […] And the fact that it's now taken up by others to bring it to higher scales. If it would have been in the wrong direction, it wouldn't have been now taken up by big corporations and these public-private partnerships.*" – Project Officer

However, experts point to the fact that this is an example from general aviation, not commercial aviation. There are technologies that cannot be scaled to larger aircraft segments. One of these areas is batteries because the energy density limits the achievable range. Fuel cells will need to be used for larger aircraft. The use of hydrogen for aviation has been funded by the framework programmes and is now being taken up by the Clean Aviation Joint Undertaking and will be enlarged and build-upon for bigger aircraft.

Next to MAHEPA, ULTIMATE, SMS and PARSIFAL are featured as H2020 success stories in aeronautics.[18]

Interviewees also mentioned one project that was not able to resolve different views on the feasibility of a new aircraft configuration. The advantages of the technologies could not be demonstrated in light of the cost associated with changes necessary as a follow-on, which went as far as changes in airport layout.

One interviewee described the results of European research efforts as a good and steady flow of technology development, making existing technologies more efficient and working on next-generation developments. But they also pointed out that breakthrough innovation will not be possible by walking in the established paths.

9.3.4.7. Policy & Standards Pathway

Civil aviation is tightly regulated to help ensure the highest levels of safety. Regulatory authorities are encouraged to join projects to engage them in the process of research and development to anticipate and prepare certification aspects and to provide guidance without formal endorsement.

The involvement of the regulatory authority EASA was mentioned for one of the projects in this case study. This was seen as beneficial because it was possible for EASA to learn about the novel technology. This will help for future certification of such products. Their involvement could be improved, though. They were willing to cooperate, but how to involve them was perceived as unclear and as a bureaucratic problem.

According to interviewees, the development of a new rule for certification might take ten years or longer. The process is being perceived as very bureaucratic, with a lot of documentation to be provided. There will be a need for new certification processes with new aircraft designs and architectures, with electrification and hydrogen coming. Certification processes need to become more digital. There is also ongoing research into how and to what extent Artificial Intelligence can support design and certification without compromising safety.

The EASA and the American FAA both have established working groups to work on easier and more digital certification procedures. For example, the EASA is working on a virtual protocol for certification; this is referred to as new, unchartered territory by an interviewee. The results of the research projects help prepare the evidence for standardization bodies.

9.4. Conclusion

EQ 3.2. To what extent have the programme implementation processes in this area influenced the types of projects selected?

Implementation processes follow the standard for European calls and seem to be suitable for identifying proposals that address new research areas and might lead to ground-breaking innovation. With the calls directed at breakthrough-innovation, very aspirational goals had been formulated which were not prescriptive. This led to a large number of proposals being submitted covering a wide range of different areas and technologies. With more budget allocated to partnerships in H2020 than in FP7, a much higher level of competition was present than in the framework programmes before. Even very high-scoring proposals could not be retained due to the small size of the budget available. To be able to assess the diversity of different proposals, it is essential to have diverse experts with complementary backgrounds – industrial as well as academic – to do the evaluation process.

One interviewee suggests publishing calls already at a draft stage to give as much time as possible for researchers to develop proposals. This would need to be agreed by all member states, though, to provide a level playing field.

EQ 4.1. What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results all together leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

The expected impact of the analysed calls was to demonstrate the potential and mature the TRL of their research objects to prepare the ground for future highly innovative breakthrough products and services for European aviation, significantly decreasing emissions and greening aviation as well as enhancing the competitiveness of the aviation industry.

Projects in the portfolio were able to generate significant improvements in performance as well as increase the maturity of the involved technologies. Some of the projects can be considered pioneering and demonstrate the potential of, for instance, electric aviation and hydrogen in aviation. Projects have also contributed greatly to the development of new materials. Altogether, the projects' results are therefore leading to the achievement of the programme's objectives in this area.

Thus said, efforts are by far not sufficient to reach zero emissions in commercial aviation in the foreseeable future. While there are promising results for small aircraft segments and effort is directed at hydrogen aircraft with Clean Aviation Joint Undertaking, interviewees doubt that with the pace and route taken, zero emission aircrafts will be introduced by 2050 on a large scale. Hydrogen in aviation needs to be economically viable, and it will need to be a worldwide decision with the US, China and other large nations agreeing to work in the same direction because it is a worldwide infrastructure that needs adjusting.

E.Q 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact?

This case study identified a set of internal factors for establishing an effective portfolio that is influencing the progress of the interventions positively towards the intended impact.

Building on previous project results: Building on learnings from preceding projects and research in the area helps to further mature technologies towards higher TRL.

Bringing excellence together: Successful consortia manage to bring together the best researchers and industry experts in their respective fields.

Integration of partners from other industries: Aviation research benefits from experience gained in other industries, for example, automotive. Research projects can open markets for new actors.

Working with regulatory authorities: Integrating regulatory authorities in the development of novel technologies early on helps reduce the time for certification.

Barriers to achieving impact could also be identified in the case study. Some of these can be considered as barriers internal to the Framework Programme:

Small budgets: Compared to investments in other areas, the budget allocated to ground-breaking research is rather small. More results could be expected with larger investments.

Aviation as a conservative industry: The aviation industry tends to rely on established networks where trust has already built up. This makes it difficult for new actors to enter the arena.

OEMs are risk averse: With safety being paramount, OEMs tend to avoid taking risks. This hinders and slows down the uptake of new technologies.

Fewer Scientific Officers: A reduction in the number of Scientific Officers at the Commission left a resource as well as a competency gap.

There are also some challenges lying ahead that have the potential to become barriers to a green transition towards zero emission aircraft or aviation in a broader sense.

Strategic steer: Interviewees point out that there should be a stronger steer from the Commission setting even more ambitious targets. An independent advisory board could play an important role, one that is rather independent of the industry and is composed of all relevant groups encompassing research, citizen representatives, and representatives from different transport modes as well as other industries. This might also put a higher emphasis on societal needs (e.g. noise reduction).

Keeping high standards of safety: One major accident with electric aviation and the whole project might be at risk.

Airport infrastructure: For hydrogen storage and possibly new aircraft configurations, there are challenges that might make it necessary to adapt airport infrastructure or infrastructure near airports. Investments needed are large, and therefore, reliable planning roadmaps are essential. This means far-reaching decisions need to be taken now.

Looking beyond the aircraft: Much higher reductions of greenhouse gas, as well as noise emissions, could be achieved from using alternative transport modes[19] – in other words: not flying at all – or flight operations (e.g. climate optimized flight routes). These options are not challenging from a technological point of view but challenging in implementation; they require political will.

Green energy supply: A general problem that does not only apply to aviation is the need for renewable energy to match the demand, which might even be rising.

EQ 4.3. To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts?

Dissemination measures follow a usual pattern for technology and innovation pathways, with academic papers being very important. In addition, students are seen as an important stakeholder group with the future talent needed not only to push research but also in the production of new aircraft types. Projects were able to integrate students in their work.

Communication for the public needs to take into account that there might be objections to novel technologies. Producing short videos of some of the projects was seen as powerful in making results easily understandable to a wider public.

EQ 5.1. What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

The most important added value is that for some of the participants, research would not have been possible at all in the lack of national funding programmes dedicated to research in the field of aviation. Access to research infrastructure which would not be available on a national level, is another aspect as well as engaging regulatory authorities is also easier at a European level.

With the recent changes in strategy, the EU is also changing its perspective: reducing greenhouse gas emissions becomes more important than the competitiveness of the industry. This serves as a stimulus for the industry to set more ambitious targets and invest in research.

EQ 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

In 2020, it was estimated that a share of 7.7 % of the total turnover of civil aeronautics was invested in R&D activities by private and public stakeholders[20]. Support from the EU institutions through EU-funded research programmes is essential in playing a leading role in developing future green technologies for civil aviation. With the sector's high investment in R&D, there is a contribution to SDG 9: Industry, Innovation and Infrastructure, as well as with the focus on zero emission aircraft, a contribution to SDG 12: Responsible Consumption and Production is given.

9.5. Annexes

9.5.1. Key metadata of the case study No. 9 'Zero Emission Aircraft'

Case study no. 9	**Zero Emission Aircraft**
Evaluation Question addressed	EQ 3.2.; 4.1.; 4.2.; 4.3; 4.4.; 5.1.
Area	Transport and Mobility
Programme parts	Horizon 2020 Work Programme 2014 – 2015, 11. Smart, green and integrated transport. Revised. Horizon 2020 Work Programme 2016 – 2017. 11. Smart, green and integrated transport.
Scope	3 Horizon 2020 calls Time horizon covered: 2015 – 2022 Number and type of instruments analyzed: 3 RIAs Number of projects analysed: 14
Key data sources	H2020 Work Programmes & relevant call text Project data from CORDIS & CORDA 7 interviews (1 Member of ACARE chairteam, 1 Expert with background in academia in aeronautical engineering and industry, 1 Expert with background in academia in aircraft instrumentation and avionics as well as member of a range of national and European advisory committees in aviation research, 1 expert on alternative, hybrid-electric propulsion systems, 1 Policy Officer, 1 Expert/Partnership Representative, 1 Project Beneficiary) Strategic Policy Documents
Links with partnerships	JU Clean Sky 2
Relevant policies, strategies and visions	Vision for 2020: Meeting society's needs and winning global leadership, ACARE 2001 Flightpath 2050 Europe's Vision for Aviation, ACARE 2011 EU Transport White Paper, 2011 Aviation Strategy for Europe, 2015 European Green Deal, 2019 Mobility Strategy, 2020 Destination 2050, 2021 Fly the Green Deal, ACARE 2022 Alliance for Zero-Emission Aviation, 2022 Sustainable Development Goals 9 and 12

9.5.2. Project list of the case study No. 9 ‘Zero Emission Aircraft’

Table 83. Project information.

Project Acronym	Project Title	Topic Code	Action Type	Project Start	Project End
ULTIMATE	Ultra Low emission Technology Innovations for Mid-century Aircraft Turbine Engines	MG-1.5-2014	RIA	01/09/2015	31/08/2018
ASuMED	Advanced Superconducting Motor Experimental Demonstrator	MG-1-4-2016-2017	RIA	01/05/2017	31/08/2020
PARSIFAL	Prandtlplane ARchitecture for the Sustainable Improvement of Future AirpLanes	MG-1-4-2016-2017	RIA	01/05/2017	31/08/2020
CENTRELINE	ConcEpt validatioN sTudy foR fusElage wake-filLIng propulsioN intEgration	MG-1-4-2016-2017	RIA	01/06/2017	30/11/2020
AERIALIST	AdvancEd aicRaft-noIse-AlLeviation devIceS using meTamaterials	MG-1-4-2016-2017	RIA	01/06/2017	31/05/2020
INCEPTION	Incremental Nonlinear flight Control supplemented with Envelope ProtecTION techniques	MG-1-4-2016-2017	RIA	01/06/2017	30/11/2020
ACASIAS	Advanced Concepts for Aero-Structures with Integrated Antennas and Sensors	MG-1.1-2016	RIA	01/06/2017	31/05/2021
NHYTE	New Hybrid Thermoplastic Composite Aerostructures manufactured by Out of Autoclave Continuous Automated Technologies	MG-1.1-2016	RIA	01/05/2017	31/10/2020
MAHEPA	Modular Approach to Hybrid Electric Propulsion Architecture	MG-1.1-2016	RIA	01/05/2017	31/10/2021
SMS	Smart Morphing and Sensing	MG-1.1-2016	RIA	01/05/2017	30/04/2020
SABRE	Shape Adaptive Blades for Rotorcraft Efficiency	MG-1.1-2016	RIA	01/06/2017	31/05/2021
HARVEST	Hierarchical multifunctional composites with thermoelectrically powered autonomous structural health monitoring for the aviation industry	MG-1-4-2016-2017	RIA	01/09/2018	30/11/2021
STRATOFLY	Stratospheric Flying Opportunities for High-Speed Propulsion Concepts	MG-1-4-2016-2017	RIA	01/06/2018	31/05/2021
H3PS	H3PS – High Power High Scalability Aircraft Hybrid Powertrain	MG-1-4-2016-2017	RIA	01/05/2018	31/03/2022

9.6. References

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[4] Pare project (2020): Chapter 8 Emerging Aviation Technologies; https://www.pareproject.eu/publications [25.09.2022]

[5] ibid

[6] COM(2011) 144 final, “White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system“

[7] Reductions relative to the capabilities of typical new aircraft in 2000.

[8] COM (2015) 261 final, “An aviation strategy for Europe”

[9] COM(2019) 640 final, „The European Green Deal”

[10] COM(2020) 789 final, „Sustainable and Smart Mobility Strategy – putting European transport on track for the future“

[11] https://www.destination2050.eu/ [26.09.2022]; Van der Sman et al. (2021): Destination 2050 – A route to net zero European aviation; https://www.destination2050.eu/wp-content/uploads/2021/03/Destination2050_Report.pdf

[12] ACARE (2022): Fly the Green Deal, Europe’s Vision for Sustainable Aviation, Report of the Advisory Council for Aviation Research and Innovation in Europe (ACARE), p. 20.

[13] https://defence-industry-space.ec.europa.eu/eu-aeronautics-industry/alliance-zero-emission-aviation_en [26.09.2022]

[14] Horizon 2020 Work Programme 2014 – 2015, 11. Smart, green and integrated transport. Revised. p. 12-13

[15] Horizon 2020 Work Programme 2016 – 2017. 11. Smart, green and integrated transport. p. 12-13

[16] Horizon 2020 Work Programme 2016 – 2017. 11. Smart, green and integrated transport. p. 17-18

[17] COUNCIL REGULATION (EU) No 558/2014 of 6 May 2014 establishing the Clean Sky 2 Joint Undertaking

[18] https://ec.europa.eu/research-and-innovation/en/projects/success-stories/all?field_project_participants_target_id=All&field_sus_themes_target_id=67&field_sus_themes_target_id_1=1209&project_acronyms=All&field_project_number_value=&field_project_coordinator_value=&field_project_duration_value=&field_project_duration_end_value=&page=2

[19] See also EEA (2020): Transport and environment report 2020: Train or Plane? EEA Report No 19/2020

[20] ASD Facts & Figures 2020. https://www.asd-europe.org/sites/default/files/atoms/files/ASD_Facts%26Figures_2021_.pdf

10. Case study 10: Sustainable and healthy urban transport

10.1. Summary

This case study analyses the H2020 project portfolio related to Sustainable and Healthy Urban Transport and comprises transport solutions related to, e.g. cargo bikes, cycling, bus services, micro-mobility, and parking management solutions.

The case study shows that the projects in the portfolio have contributed to achieving the EU policy priorities by creating a strong community of practice regarding the issue of urban transport. The case study shows that the projects created tangible results and impacts through the implementation of a) mobility services and technologies, b) the testing and demonstration of digital tools, c) the adaptation of legal frameworks and policy standards, d) the creation of new knowledge stocks and capacities and e) community building. Aside from these impacts, there are different learnings that can be taken away from the case study for future Work Programme design. These learnings include the importance of community platforms, the promotion of a logical investment flow, multi-stakeholder approaches in the projects, a focus on the uptake of solutions, synergetic approaches with other thematic areas, balanced approaches to flexibility and the further development of sustainable transport indicators.

10.2. Introduction and overview

10.2.1. Objectives

The sustainability of transport systems has been identified as a key area influencing the success of the European Green Deal. As one of the main sources of EU greenhouse gas emissions, the EU has set the ambitious goal to reduce these emissions by 55% by 2030 and achieve climate neutrality by 2050[1]. To reach these ambitious goals, a significant focus on research and innovation efforts is put on the topic of sustainable and healthy urban transport in Horizon Europe (Cluster 5), building strongly on the successes of the adequate results of the Horizon 2020 challenge of smart, green, and integrated transport (SC4).

Transportation is the basis of economic growth and has rural/urban, national and international aspects. It is also one of the main sources of carbon dioxide emissions (23% of all greenhouse gas emissions in the European Union[2]). The continued dependence on fossil fuels, increases in traffic and congestion in European cities due to increased use of private cars and freight/delivery traffic require a comprehensive and multidisciplinary approach to Research & Innovation in the field of transportation. Especially in the urban context, manifold interlinkages and multi-modal challenges demand new formats for introducing green transport modes.

A successful transition to green transport will establish significant economic, social and environmental benefits by reducing climate-warming greenhouse gas emissions as well as air and noise pollution, and counter their adverse health effects. The urban context, with its additional exposure to health-related concerns in terms of transport, provides a crucial field for innovation in order to achieve climate neutrality by 2050. According to the Sustainable Smart Mobility Strategy (2020), all modes of transportation need to be more sustainable and therefore need to be decarbonized.

The case study on sustainable and healthy urban transport is crucial in order to assess if the ambitious goals set out in the policy framework are sufficiently addressed by the research and innovation projects of H2020 and Horizon Europe. To do so, the case study has the following objectives:

- Determine the specific added value of EU interventions to achieve overarching policy goals (as set out in the program indicators of H2020, the Green Deal)
- Identify the main results and impacts of the projects in the intervention area
- Trace impact pathways that triggered (un)expected changes
- Illuminate internal and external factors that have influenced the progress of European Cities in this area

10.2.2. Methodology and case study structure

The analytical approach commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to Sustainable and Safe Transport for All (e.g., Transport White Paper 2011, Sustainable And Smart Mobility Strategy Putting European transport on track for the future, 2021). This led to the identification of four areas of interest for the Green Transition: a) More sustainable modes of transport, b) More sustainable alternatives (supply side), c) More sustainable choices (demand side), and d) Reducing pollution and risk. The case study Sustainable and Healthy Urban Transport is part of the case studies covering area b), with links into the other three areas.

Having identified the 4 main areas of interest for an evaluation of Horizon 2020 with respect to Green Transition in Transport, we then selected relevant project actions in Horizon 2020 based on a keyword search of topics in the work programme. For the identified projects, relevant data as available from Cordis/Corda have been compiled and analyzed and complemented by additional sources like project websites.

The analysis of the projects included in this case study is based on a triangular research approach that combines a) the analysis of programme documents (work programmes, relevant call texts) and strategic documents related to sustainable and healthy urban transport, as well as other sources communicating H2020 results (e.g. Innovation Radar, Cordis Results Packs). Based on the project portfolio selected for the case study, the second pillar of the triangulation was b) the analysis of key documents and results from the projects. Finally, c) seven interviews were carried out with relevant stakeholders. These interviews were conducted with representatives of the European Commission in charge of the topic (DG MOVE) and the implementation (CINEA), thematic experts involved in the European strategic processes (i.e. members of the European Mission Board on Climate-Neutral and Smart Cities), project coordinators of relevant projects and representatives of further stakeholder groups (e.g. European Cyclists Federation). Interviews followed a semi-structured, expert-centred approach. The design of the interview guidelines was based on the evaluation question in the focus of the given interview and the specific interview partner(s).

10.3. Synthesis of Evidence

10.3.1. Strategic policy priorities

The European Green New Deal sets out an ambitious change framework for the European Union, detailing the objectives that should be achieved in terms of the green transition in the upcoming years. Currently, transport emissions account for about a quarter of the EU´s emissions, and therefore, a considerable increase in clean vehicle and green fuel uptake is necessary to achieve the envisioned objectives.[3] Looking at the transport-specific policy goals, some key priorities are outlined in the EU Urban Mobility Framework[4]:

- A reinforced approach to TEN-T urban nodes
- A reinforced approach to Sustainable Urban Mobility Plans (SUMPs) and mobility management plans
- Monitoring progress – sustainable urban mobility indicators
- Attractive public transport services, supported by a multimodal approach and by digitalisation
- Healthier and safer mobility; a renewed focus on walking, cycling and micro-mobility
- Zero-emission city freight logistics and last-mile delivery
- Digitalisation, innovation and new mobility services
- Towards climate neutral cities: resilient, environmentally friendly and energy efficient urban transport
- Awareness raising and capacity building

These policy objectives should be approached by taking actions on all relevant levels of governance, making a strong statement for the integration of a multi-level policy framework in dedicated mobility actions. Even though these objectives were communicated only in 2021, their content allows a good reference frame for assessing the contributions of the H2020 project portfolio selected for the Sustainable and Healthy Urban Transport case study.

Furthermore, the EU Transport and Mobility strategy constitutes a key policy strategy document that outlines concrete actions and initiatives that should be implemented in order to promote sustainable transport. Hereby, the case study aligns with the following flagships of the EU Transport and Mobility strategy[5]:

- Flagship 1 Boosting the uptake of zero-emission vehicles, renewable & low-carbon fuels and related infrastructure
- Flagship 3 Making interurban and urban mobility more sustainable and healthy
- Flagship 6 Making connected and automated multimodal mobility a reality
- Flagship 7 Innovation, data and Artificial Intelligence for smarter mobility
- Flagship 9 Making mobility fair and just for all

Going beyond the immediate scope of the Framework Programmes, the case study also links to other funding schemes, such as the Joint Programming Initiative Urban Europe. Specifically, the case links to the ERA-Net CoFund Urban Accessibility and Connectivity (ENUAC), as well as the ERA-Net Cofund Smart Cities and Communities (ENSCC), which have a strong participatory element to meet urban challenges and lead to new approaches, tools, instruments, insights and knowledge. Moreover, the case study links to the EIT Urban Mobility, which puts a focus on engaging citizens and new mobility solutions. However, as the focus of the case study explicitly lies on the H2020 projects, the activities of the aforementioned initiatives will not be part of the analysis.

10.3.2. Horizon 2020 programming related to Sustainable and Healthy Urban Transport

As the policy objectives above outline, there are various pathways for tackling the issues that pertain to the field of sustainable and healthy urban transport. The H2020 work programmes 2014-2015 and 2016-2017 already addressed different aspects of these issues that have now taken the form of the policy objectives introduced before. For the purpose of getting to a useful and meaningful assessment of the H2020 contributions to the topic of sustainable and healthy urban transport, the following calls have been identified for analysis:

Table 84. H2020 work programme calls, impacts and challenges.

H2020 call	Expected Impact	Specific challenge
MG-3.2-2014 - Advanced bus concepts for increased efficiency	To improve public transport in Europe through more attractive buses that contribute to strengthening the leading role of European industries in the sector, in particular through the development of standard components by the bus manufacturers and by the demonstration of at least a 30% reduction of energy needed for climate control while complying with Real Driving Emissions limits set by the established Euro VI procedures.	The challenge is to increase the modal share of public passenger transport, in particular by bus, and also promote co-modality. In addition, the economic situation today highlights the importance to study solutions for all segments of the urban bus market, capable to improve the attractiveness through innovative solutions for increased efficiency of the system. In particular energy consumption of auxiliaries in a bus represents a significant part of the overall consumption, heavily impacting energy efficiency performances.
MG-5.5a-2015 - Demonstrating and testing innovative solutions for cleaner and better urban transport and mobility	To produce added-value inputs to the development of European knowledge base on the effectiveness and impacts of innovative mobility solutions and approaches to their successful implementation	Many of Europe's urban areas are struggling to address the transport-related challenges they are facing. New technologies and innovative measures are emerging, but they are not taken up at a scale that is necessary to meet the targets of the Transport White Paper. Cities are hesitating to implement innovative solutions because little information is available on their effectiveness and on how to overcome the barriers to successful implementation. Special attention should be paid to issues related to vulnerable groups of citizens and gender issues.
MG-4.1-2017 - Increasing the take up and scale-up of innovative solutions to achieve sustainable mobility in urban areas	Projects will lead to faster, more cost-effective and larger scale deployment of a range of innovative (technological and non-technological) solutions/approaches to achieve sustainable mobility in urban areas.	Many innovative solutions (supported by STEER, CIVITAS, national, regional, local, international and other initiatives) for sustainable urban mobility were locally developed or developed as self-standing projects in a variety of social, economic and geographical contexts. The specific challenge is to increase the take up of innovative solutions by transferring them to new contexts and studying and comparing the impacts. Special attention should be paid to social issues and implications. Where relevant, potential gender differences should be investigated.

The selected calls and the expected impacts and specific challenges pertaining to them set the framework for the objectives of the work programme as regards sustainable and healthy urban transport. The analysis of the case study will try to answer how much the projects have contributed to these expected impacts and specific challenges.

10.3.3. Project portfolio characteristics

The project portfolio of the case study Sustainable, and Healthy Urban Transport includes 7 projects with a total EC contribution of just under € 74 Million(M). The greatest share of the budget allocation, almost half of the total budget (48%, see Table 1), went to public bodies, followed by for-profit organisations with a share of 25% of the total funding. Compared to the other SCs, the funding share of the public bodies in the case study Sustainable and Healthy *Urban Transport* projects is exceptionally high (48% against an average of 5% among all Green Transition thematic areas, SC2 to SC5). The funding share of the for-profit entities, however, is almost only half of the budget in Green Transition areas (25% against an average of 47% among all Green Transition areas, SC2 to SC5). Although the public bodies have received relatively higher funding, the share of participation in the projects is higher among for-profit organisations (38%) compared with public bodies (33%).

Table 85. Type of organisations in Case Study Sustainable and Healthy Urban Transport.

Type of organisation	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1000)	EC contribution Share (%)	EC Contr. per part. (EUR 1000)
HES	7	18	8%	5,175	7%	287.5
OTH	7	27	13%	10,327	14%	382.5
PRC	7	81	38%	18,471	25%	228.0
PUB	7	70	33%	35,277	48%	504.0
REC	6	16	8%	4,524	6%	282.7
Total (All types)	**7**	**212**	**100%**	**73,773**	**100%**	**348.0**

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

Source: eCorda, own elaboration.

Although higher or secondary education establishments and research organisations usually receive higher shares of funding, in this specific case study, their contribution and funding shares are lower. The funding share of higher or secondary education establishments is 7%, followed by research organisations with 6%, and other types of organisations that do not fit those categories received 14% of the total EC contributions.

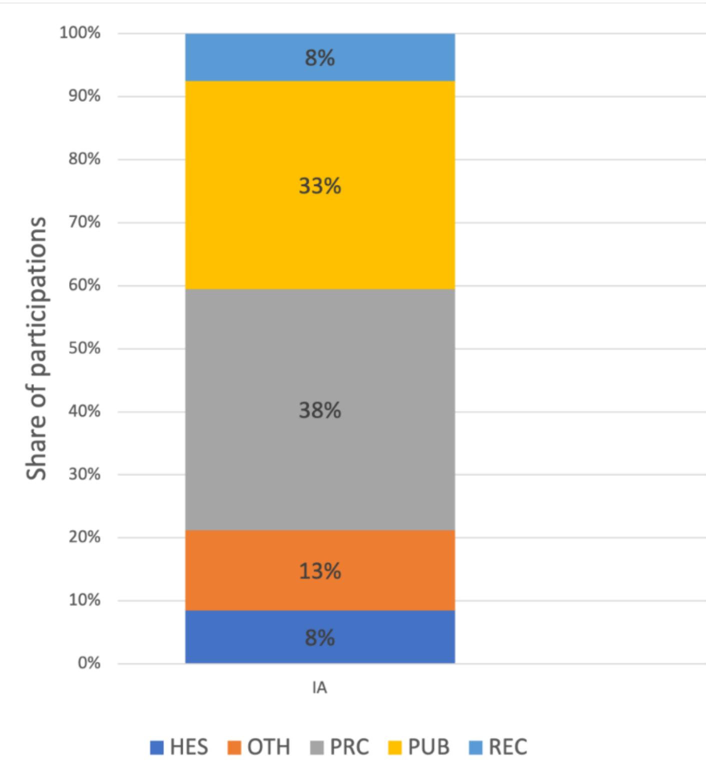


Figure 240 Share (%) of participation by type of action/instruments.

Source: eCorda, own elaboration.

In this case study, all the available funding is allocated to Innovation Actions (IA), indicating an emphasis on the goal of planning new/improved products, processes, and services (see Table 88 and Figure 259); there is no representation of the other actions whatsoever. However, in the general frame of Urban Transport, CSA like the CIVITAS platform, play a crucial role in coordinating and connecting the different IAs. IAs usually include relatively higher participation of private entities in comparison with other organisation types. Participation in the case study Sustainable, and Healthy Urban Transport reflects the same pattern, 38% of the participation is coming from private for-profit entities (PRC), followed by public bodies (PUB) with 33% participation.

Table 86. Type of actions/instruments (grouped) in case study Sustainable and Healthy Urban Transport.

Group of Action/instrument	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)
		Nb	Share (%)	EUR (1,000)	Share (%)	
IA	7	212	100.0%	73,772.9	100.0%	348.0
RIA	0	0	0.0%	0.0	0.0%	N/A
CSA	0	0	0.0%	0.0	0.0%	N/A
SME	0	0	0.0%	0.0	0.0%	N/A
Other	0	0	0.0%	0.0	0.0%	N/A
All types	**7**	**212**	**100.0%**	**73,772.9**	**100.0%**	**348.0**

Source: eCorda, own elaboration.

EU-27 countries accounted for close to 92% of the participation in the case study (see Table 89). The most visible EU-27 country in the case study is Germany, with a participation share of just under 11%, followed by France with 7% (see Table 4). Although the number of projects is similar between EU-14 (7 projects) and EU-13 (6 projects) countries, there is a visible gap between the participation/funding shares. EU-14 countries (13 countries in total) received approximately 78% with a participation share of 74.5%, while EU-13 (11 countries) received 14% of the total funding pool with a participation share of 16.5 %. Despite this difference, the funding share of EU-13 countries is still quite higher than the aggregated calculation of all the Green Transition areas (6%).

Excluding the United Kingdom (UK), two associated countries were present in two different projects and received 0.5% of the funding. The UK participated in 6 of the projects with a share of 7.6% of the total funding contribution from EC. This makes the UK one of the 5 most visible countries in terms of funding share in this case study. The UK is the only country without an EU membership amongst the 15 most visible countries.

Table 87. Group of countries (of supported organisations) in Case Study Urban.

Group of country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Number of countries
		Nb	Share (%)	EUR (1,000)	Share (%)		
H2020-EU27	7	193	91.0%	67,765	91.9%	351.1	24
EU-14	*7*	*158*	*74.5%*	*57,477*	*77.9%*	*363.8*	*13*
EU-13	*6*	*35*	*16.5%*	*10,288*	*13.9%*	*294.0*	*11*
H2020-associated (exclude UK)	2	3	1.4%	380	0.5%	126.5	2
United Kingdom	6	14	6.6%	5,628	7.6%	402.0	1
Third Countries	2	2	0.9%	0	0.0%	0.0	1
All-countries	**7**	**212**	**100.0%**	**73,773**	**100.0%**	**348.0**	**28**

Source: eCorda, own elaboration.

Although the statistics from Horizon 2020 display a relatively high number of collaborations from associated and third countries, the case study projects include only a single third country. Both the participation and funding share of the third country (China) stays under 1%.

Table 88. The most visible countries of supported organisations in Case Study Urban.

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Order
		Nb	Share (%)	EUR (1,000)	Share (%)		
Germany	7	23	10.8%	7,440	10%	323.5	1
France	6	15	7.1%	3,505	5%	233.7	2
United Kingdom	6	14	6.6%	5,628	8%	402.0	3
Italy	6	27	12.7%	8,590	12%	318.1	4
Spain	6	28	13.2%	9,891	13%	353.2	5
Belgium	5	19	9.0%	8,693	12%	457.5	6
Romania	4	10	4.7%	2,190	3%	219.0	7
Netherlands	4	7	3.3%	1,758	2%	251.1	8
Portugal	4	9	4.2%	4,402	6%	489.1	9
Bulgaria	3	4	1.9%	1,184	2%	296.1	10
Denmark	3	3	1.4%	791	1%	263.7	11
Sweden	3	12	5.7%	4,551	6%	379.3	12
Finland	3	8	3.8%	3,873	5%	484.2	13
Austria	3	3	1.4%	1,134	2%	378.0	14
Poland	3	5	2.4%	511	1%	102.2	15

All of the coordinating organisations are from the EU-14 countries. Even after considering the high percentage of coordinating organisations from the EU-14 countries (80% across all SCs), the number is higher (100%). In terms of coordination, Belgium is the most active country with 3 coordinated projects (42.9%) (see **Error! Reference source not found.**). The remaining 4 organisations are from Netherlands, Portugal, Italy, and Spain.

Table 89. The most visible countries of coordinating organisations in Case Study Urban.

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Order
		Nb	Share (%)	EUR (1,000)	Share (%)		
Belgium	3	3	42.9%	4,957	53%	1,652.2	1
Netherlands	1	1	14.3%	668	7%	668.3	2
Portugal	1	1	14.3%	1,533	16%	1,532.7	3
Italy	1	1	14.3%	415	4%	415.4	4
Spain	1	1	14.3%	1,810	19%	1,810.4	5

The network analysis of the participating countries in the case study Urban also displays the collaboration cluster between the most visible EU-14 countries together with the UK (see Figure 260). The number of collaborations is exceptionally high between Germany, Spain, Italy, France, the UK, Belgium, Portugal, and Sweden. Romania seems to be the most visible EU-13 country, frequently collaborating with the countries in the inner cluster.

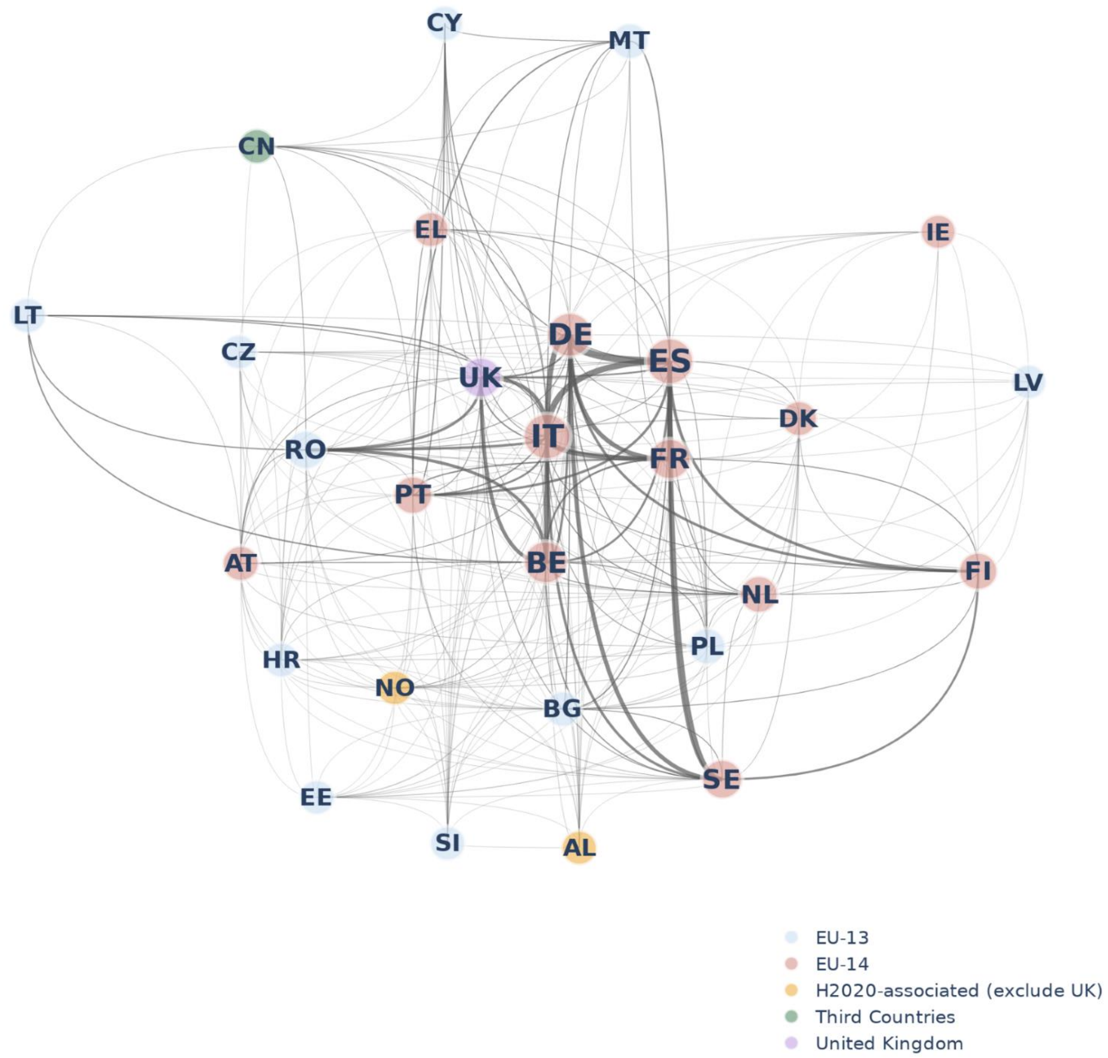


Figure 241 Network of participating countries in the case Study "Urban".

10.3.4. Results of the Horizon 2020 funding activities: pathways to impact

The figure below shows the outcomes for SC4 in the H2020 Theory of Change.

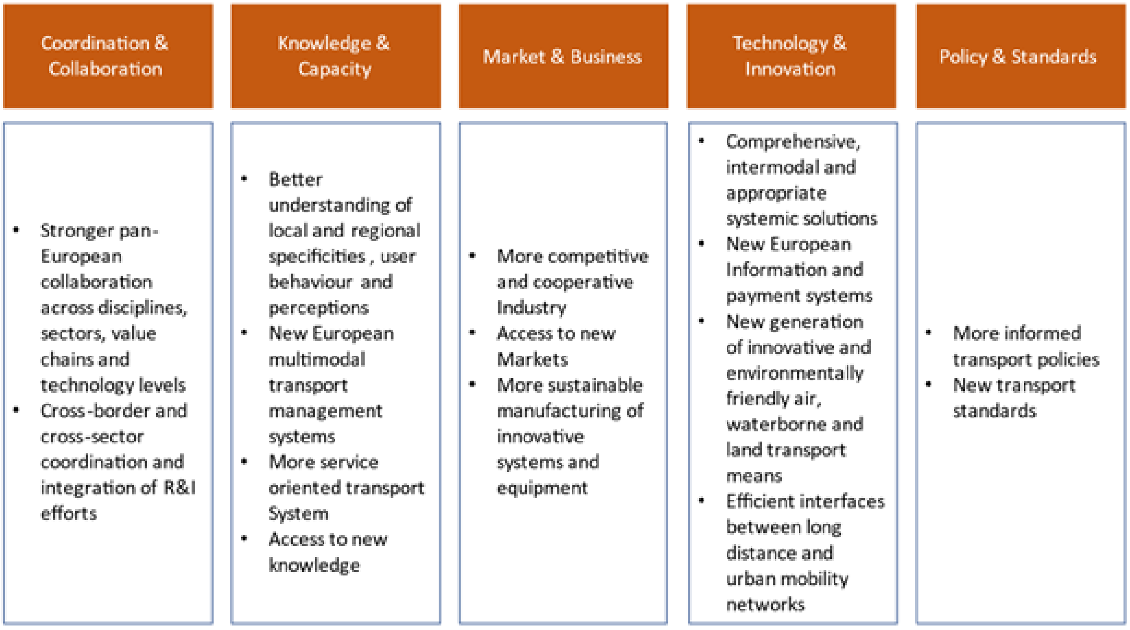


Figure 242. Expected Outcomes across all analysed calls.

The following sections will provide evidence for each of the pathways.

10.3.5. Coordination & Collaboration Pathway

Bringing together different types of stakeholders to facilitate collaboration across disciplines, sectors, value chains and technology levels was of considerable importance for the selected projects in the case study of Sustainable and Healthy Urban Transport. However, as the analysis of the e-cordis participation data has shown, not all of the stakeholders were represented equally in the projects (see section 2.4.1). The collaboration between public authorities and private for-profit entities was one of the key achievements of the projects in the analyzed portfolio.

"In the frame of the CIVITAS platform, it worked very well […] and created a stable core of stakeholders for urban transport transformations"– Project beneficiary and transport expert

A crucial impact that started to materialize through the various projects hereby was that cities, as major actors in urban transport, were able to engage with each other, form networks and support each other in their efforts to create more sustainable transport systems. The interviewees highlighted frequently that the CIVITAS frame provided an important coordination tool for their IA projects in order to deploy an integrated innovation approach.

Further, it was pointed out by the interviewees that the transformation towards sustainable and healthy urban transport systems requires many cities to test solutions adapted to their specific context, and that is exactly what was enabled through the H2020 project portfolio. The interviewees regarded as especially useful the implementation of close-to-market innovations and the exchange of best practices, e.g. in parking space management, cargo bike usage, and system bus concepts.

"Thanks to the Horizon 2020 projects, we have a lot of cities where they have tested solutions, solutions that will continue to exist" –Policy representative

The inclusion of different types of stakeholders and the mobilisation of a broader collaboration basis have also played a positive role in the projects. In the case of ESBF_2, the collaboration between bus stakeholders and researchers focused on 6 research areas and assessed the viability of innovative technologies and their application to over 200 vehicles in 12 different European bus networks. Furthermore, taking different types of stakeholders in different cities into consideration improved the innovativeness and efficiency of the considered solutions by enriching the diversity of approaches and ideas informing the solutions. The focus on the characteristics, needs, and expectations of both tourists and residents in touristic locations CIVITAS DESTINATIONS (especially on islands like Elba and Madeira where the transportation infrastructure planning is particularly challenging) allowed to develop strategies for the long-term, integrated transportation solutions fitting the needs of both stakeholder types. Furthermore, shared mobility options (e.g. e-bike sharing system) caused positive results for the health and liveability of tourist destinations (both for tourists and residents).

As a further type of collaboration, strengthening the network between different urban transportation forms serving different types of functions yielded significant results. The collaboration in PORTIS between cities and their ports created direct benefits in cities like Antwerp, with a 28% increment in cycling in the city, including a significant increment in cycling among port commuters. Aberdeen, Klaipeda, and Trieste have also experienced direct improvements in freight movements travelling on principal roots instead of residential roads and in CO2 emission levels as well as in pedestrian infrastructure by improving the collaboration between multi-modal transportation forms.

"Bringing about transformations means exploiting synergies" – Transport Expert

Although the establishment of networks of collaboration between actors who did not work together before was generally held in high regard by the interviewees, it was also mentioned that sometimes synergies couldn´t be used as effectively as it would be desirable. While the projects, for example, succeeded in building up a European transport and urban mobility community, some stakeholder groups (like the transport industry or also small-scale initiatives for transformation on the grassroots level) were less active in this process, according to some interviewees.

10.3.5.1. Knowledge & Capacity Building Pathway

Building up knowledge and capacities for sustainable and healthy urban transport played a relevant role in the different projects of the case study. Although all the analysed projects are classified as IAs, making capacity building a subordinated goal in comparison to new products, services and processes for transport, it remained present. In fact, different key results of the projects were related to knowledge and capacity building, especially on the level of cities and municipalities. For example, the EBSF2 project focused strongly on building a knowledge base on international bus systems and how they could be adapted to different contexts and investment capacities. The specific challenges are unique to local contexts, and therefore, local capacities and knowledge bases need to be developed accordingly.

"*Transport is a unique sector with unique dynamics*" - Project beneficiary and transport expert

In terms of knowledge sharing, the interviewees frequently mentioned the CIVITAS platform, which provides a dedicated space for the exchange of knowledge and allows them to connect with other cities or transport actors in challenges facing similar problems. In a different direction, the Park4SUMP project initiated a capacity-building process about the strategies to develop national government laws and regulations to use innovative and effective parking management systems, including 14 national governments, increasing their knowledge about parking management greatly. Additional capacity-building training was also offered for the ParkPAD (audit tool) test in each of the selected cities, with the addition of 10 cities from the external consortium.

Capacity building hereby is not only of key importance for the uptake of innovative solutions in the regional contexts but also relates to the question of monitoring and evaluating transformative changes in urban transport settings. As one of the interviewees pointed out, the public authorities, especially on the municipal level, often don´t have the capacity or resources to oversee transport changes and deliver data for indicators of change in an adequate manner due to a lack of personnel, skills or access to data. This is both a challenge and impact of H2020 projects in the portfolio, building up these capacities with municipalities and being confronted with regular changes in terms of the administrative personnel.

"*There is a huge work related to the exchange of knowledge and capacity building for local authorities that will lead in the next step to the take up of solutions. [..] This is very important [because] if you have a certain way of including electric buses in Stockholm […], this will not work the same way in Italy. However, they can match and team up and learn from one another, and this sharing is very valuable for the community."* - Programme representative

10.3.5.2. Market & Business Pathway

In terms of creating new markets and a more competitive industry, the portfolio of projects delivered impacts mostly in terms of linking digital solutions with different transport issues of cities (e.g. a sustainable parking system, as the interviewees pointed out). The projects in the case study focused on facilitating the uptake of different (digital) solutions for urban transport issues. The Park4sump project, for example, tested new models for parking space management and created a digital tool for managing parking spaces in cities and municipalities, setting up the preconditions for innovative parking systems.

"*Civitas projects act like testbeds for scale up, and all the cities involved […] test and demonstrate on a certain scale and in a certain area the market solutions. […] This is very valuable as no public authority will invest in a technology [that is not tested]. The projects are priceless as they build the trust of the investors in deploying [these innovations] on a large scale.*" – Programme representative

There are also indirect positive effects of innovative urban planning. In the case of cycling-related implementations generated in the Handshake project, a positive consequence of a physically active community is increased productivity in the workplace, as employees who use cycling as a means of transport experience significantly fewer sick days. Furthermore, higher revenues in shopping areas located in the proximity of the intervention areas as well as positive net social benefits compared to the value of the investment by the cities, are expected to cause economic growth in the urban areas. In a similar fashion; the analysis in CIVITAS DESTINATIONS found that implementations like shared mobility (e.g. e-bike or ride-sharing services) and active transportation modes (e.g. transportation. cycling and walking paths), the optimization of the public transportation infrastructure, and the uptake of the electric vehicle types also have indirect economic and health benefits for the society.

The interviewees highlighted that the project portfolio produced noticeable results in terms of new business models for mobility as a service, opening up pathways for economic growth in the urban areas of the EU. While this was mostly acknowledged as an impactful strategy contributing to the generation and uptake of new business models, it was also noted that:

"*Transport is something that is not just for business, because it is a public right to move regardless of the wealthiness of your area or your capability to pay for certain services*." – Project Beneficiary

However, as stressed in CIVITAS DESTINATIONS, in tourist areas (especially in isolated areas like islands), the private transportation network (e.g. taxis, tourist guides, tourist busses, etc.) are in constant competition with public transport. Therefore, it is an important challenge in the way of a significant transformation for public transport operators to attract a higher share of the tourist and resident population to accumulate demand for public transportation.

10.3.5.3. Technology & Innovation Pathway

The projects in the work programs focused on deploying new and innovative solutions for urban transport systems in a different context and creating impact by facilitating the uptake of new tools, concepts, products and services. In this context, the role of infrastructure was a crucial topic that was tackled by the projects, according to the interviewees. For example, in the realm of electric mobility in port cities, cargo bike usage or bus systems. Hereby, according to one interviewee, the main impact was that:

"*innovation and research by and for the industry were immediately linked to governance; this means that solutions are linked to actual problems*". - Project beneficiary and transport expert

This linkage to genuine problems of the participating cities and regions was highlighted by the interviewees as a beneficial added value of the projects in H2020, as the cities were able to bring in their own needs and requirements and drive further their own agenda in the framework of different overarching policy frameworks. The innovation component of the projects hereby targeted various levels of actors and adapted existing solutions in creative ways to the specific infrastructural circumstances as one interviewee describes:

"A*ll [the participating] cities implemented different cargo bike measures, whether it was providing cargo bikes for their local businesses, whether it was sharing schemes and try out schemes for inhabitants, families with children or similar, like last mile deliveries for local shops, local businesses […] For example, the city of Dubrovnik in Croatia has a very specific infrastructure. Trucks and lorries cannot access the old city centre, so they had to unload in front of the city gates. And then until now, they were using old carriages with trailers. But [thanks to the project] they now switch to cargo bikes which are more efficient, faster, easier to navigate and to go in all of these narrow streets."* – Project Beneficiary and CSO representative

Furthermore, there are other examples of concrete technology innovations that aim to improve aspects of urban transport, such as the energy efficiency of transport modes. E.g. EBSF_2 analysed technologies for electric buses that cut the energy demand by 15-60% by optimising/improving heating, ventilation, and air conditioning systems and tested different types of advanced energy efficiency solutions to validate their effectiveness under real-life conditions. The project also examined different types of fuels (diesel, hybrid, and electric buses) in terms of efficiency, comfort, and safety. Project results have further confirmed that the buses using green energy types also enable technologies that increase efficient fuel use like green driver assistance systems minimising unnecessary stops and starts. Additionally, simulation approaches further confirmed that electric buses are also the most efficient ones in terms of comfort, safety, and accessibility, on top of being the most energy-efficient bus type.

Besides the testing of bus concepts, other projects explored and demonstrated concrete multi-modal transport solutions in different contexts. For example, CIVITAS DESTINATIONS, even in relatively small touristic destinations like Madeira, Rethymno, and Elba, carbon-free mobility options like electric vehicles can be encouraged by building the necessary infrastructure like e-charging stations beforehand. Therefore, regional development toward innovation technologies relies on finding synergies and associations with other EU and national financial instruments.

10.3.5.4. Policy & Standards Pathway

While all researcher projects are IAs, their contribution to creating new policies and standards for urban transport should not be underestimated, as interviewees frequently pointed out. The innovations hereby manifest themselves in adapted legal or institutional settings that are taken up by the cities participating in the different actions. This is especially true for the projects that were conceptualized as direct contributions to the refinement of Sustainable Urban Mobility Plans (SUMP) (e.g. Handshake, Park4SUMP).

"*The projects have contributed concretely to policy development by supporting the development of SUMP guidelines"* – Policy representative

In the frame of the Sustainable Urban Mobility Plans (SUMP), the projects in the portfolio have made significant contributions to anchoring different aspects of sustainable and healthy urban transport in the policy portfolio of EU cities. The interviewees stated that the SUMPs provide a very effective framing for developing a concrete agenda for the transformation of urban transport. Furthermore, the projects are also an important feedback loop for policymaking on an EU level, providing the thematically relevant DGs with an immediate quality response on policy agendas.

"*Horizon 2020 has helped us to progress in our policy-making and[allows] cities to participate actively"* – Policy representative

In the case of Park4SUMP, an assessment of the level of development from each city, as well as an early mapping/analysis of the laws, regulations, and policy measures, enabled cities to start the implementation of well-tailored parking measures and its integration into Sustainable Urban Mobility Planning (SUMP) which improved parking policies in 16 partner cities by the introduction of more than 50 parking management good practice solutions including piloting the implementation of PARKPAD, a management audit tool. Moreover, other projects like Handshake deployed tailored transition management approaches in different cities to contribute towards transformative policy development on different scales. This plethora of strategies contributed significantly to supporting sustainable and healthy urban transport in different EU cities through a concerted push towards, e.g. better cycling infrastructure.

10.4. Conclusion

EQ4.1 What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results altogether leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

Considering the specific project portfolio, the results of these projects have contributed to the achievement of the programme´s objective in multiple ways. Across the project portfolio, the following overall contributions can be summarized:

Mobility services and technologies – The projects tested and demonstrated the potential of mobility solutions in a combination of new services and technologies, including more energy-efficient bus technologies, the widespread use of cargo bikes or the multi-modal integration of transport in port cities.

Digital tools – Several of the projects developed and/or tested specific digital solutions for urban transport challenges that were developed at close-to-market levels and tested by the participating cities. This allows cities to prepare for the take up of digital transport solutions in a different context (parking management, bus system, cycling infrastructure, tourism).

Legal and policy adaptations – Embedded in the wider frame of the CIVITAS initiative and the SUMPs, the projects efficiently developed specific guidelines and policy changes in their respective domain (cycling, bus systems, cargo bikes, tourist transport, port cities).

New knowledge stocks and capacities –A crucial result of the projects was the creation of knowledge on alternative, sustainable and healthy urban transport solutions as well as the build-up of capacities for taking up the solutions after the project ended.

Community building – Creating a European community and critical mass for the transformation of transport systems through the integration of cities in the project and their connection with private and research organisations was a critical result of the project.

All the dimensions highlighted above-provided contributions to achieving the objectives of the programme in these areas and are embedded in the broader context of sustainable transport advances through the projects that include the institutionalisation of the SUMPs, the new standards for mobility management or increased recognition of the importance of cycling and walking in urban transport. As some of the projects are still not concluded, a final assessment of the achievement of objectives is not possible. However, the highlighted trends show a clear pathway towards creating the envisioned transformations, although the uptake and rollout are not always guaranteed. Here, better integration of H2020 (and Horizon Europe in the future) with other funding schemes (e.g. ERDF programmes) could be a potential leverage, as highlighted by some interviewees.

EQ4.2 Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and longer term? Are there any factors that are more or less effective than others, and, if so, what lessons can be drawn from this?

Summarising the insights of the case study, a number of observations can be made that can contribute to compiling an effective project portfolio:

Promote a logical flow of investment – The H2020 programme has lived up to the objectives set out in the work programme, but to roll out the developed and tested solutions, better integration of different investment flows is needed. This means that transmission between the different layers of innovation and investment support portfolios on a European scale needs to be integrated to support and foster the take-up and rollout of solutions.

Provide community platforms – The leverage of community building and networking (e.g. in the CIVITAS frame) was unanimously well regarded in the analysis and, therefore, should also be continued in future programmes.

Extend multi-stakeholder approaches –Related to community building, the benefits of multi-stakeholder approaches have to be highlighted in the transport sector, bringing different stakeholders together at the same table. However, there needs to be a balance between focused community building and a broad multi-stakeholder approach in the light of the EU missions.

Focus on up-take of solutions – A key element that worked well is the testing of transport solutions and the build-up of capacities. However, the uptake of the tested solutions can only be secured if it is well embedded in investment logic (see above) and the policy commitments in cities and regions.

A balanced approach to flexibility – While some interviewees lauded the stringent management, implementation commitments and monitoring frames that grant agreements provide, others also pointed out that flexibility should be easier in the projects. This would encourage bottom-up experimentation that is riskier but also provides more potential for radical innovations.

Set and collect realistic indicators – A challenge for project beneficiaries is the assessment of their impact, especially as regards often hard-to-collect indicators for certain improvement in the context of transport in cities. Here a realistic assessment of data collection for certain indicators has to be part of the proposal writing and also needs to be emphasized in the evaluation process. Frameworks like the CIVITAS process evaluation provide a good starting point.

Foster synergetic approaches – Using synergies between different projects, funding schemes, actor constellations and networks was regarded as a crucial contribution to achieving the holistic objectives of the societal missions. This should be reflected in the call and programme structure.

EQ4.3 To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts? What further actions are needed to maximise the impact of the Framework Programme interventions in this area?

Communication and dissemination measures can be an important instrument for maximizing the impact of the different projects. The portfolio of existing communication and dissemination measures applied by the project is very diverse (webinars, events, newsletters, videos, folders, best practice collections, local heroes showcasing etc.) and provides a rich pool for future projects. It became clear that the programme structure already demands a good knowledge and target plan for reaching the relevant stakeholders. Especially in the frame of public authorities, the C&D actions led to the creation of strong networks that can survive after the end of a specific project. Although the outreach to stakeholders generally worked well, there were also areas of improvement flagged, especially as regards the integration of certain domains of private industry (e.g. logistics, private transport operators, traditional transport industry) or the integration of small-scale and micro innovation projects and the amplification of their solutions.

EQ 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The work programmes provided the basis for a project portfolio that contributed towards achieving the EU policy priorities and objectives related to green transition. Most notably, the programmes enabled the operationalisation of policy objectives in a concrete (urban) setting, bringing together key actors of transport and mobility. In doing so, the projects enabled cities to work on their concrete challenges and needs in the framework of transformative change necessary to achieve EU or international policy goals. The projects did so by a) testing and demonstrating the applicability of technical, service and process innovations and b) building communities of practice committed to green transition policy goals, mutually reinforcing efforts and creating a critical mass of change actors.

EQ4.5 To what extent has international cooperation and, more specifically, association of third countries to the EU Framework Programme made a difference in achieving the environment-related objectives of the Framework Programme? Has international cooperation, and specifically association, increased the EU economic activity and jobs? (to be measured by category of Associated Countries and by Framework Programme part in order to fully assess its impact and inform future policy choices)

In the frame of the selected project portfolio, the relevance of international cooperation was minimal. As evident from the analysis of the participation numbers, only one third-country partner participated in the projects. In line with this fact, interview partners did not specifically highlight the relevance of international collaboration in the project. However, it was mentioned that an international embedding and a global view of best practices are crucial to moving transport transformations forward. In the case of the CityChangerCargoBike project, the cargo bike measures tested in the European project cities created so much attention on a global scale that after the project, some of the measures were replicated in some Latin American countries via a project financed by FedEx. This can be regarded as a best practice example for exploiting and replicating project results outside of Europe. However, no examples of this transfer of solutions into the EU were found, and therefore the value from the perspective of EU transport systems has to be considered minimal.

10.5. Annexes

10.5.1. Key metadata of the case study no. 10 – Sustainable and healthy urban transport

Table 90. Key metadata of case study no. 10 – Sustainable and healthy urban transport.

Case no. 10	**Shifting paradigms – Mobility Preferences and behaviour**
Evaluation Question addressed*	EQ 4.1, 4.2.; 4.3; 4.4.;4.5
Area	Sustainable Transport
Programme parts	WP 2014/2015 (Smart, Green and integrated Transport) WP 2016/2017 (Smart, Green and integrated Transport)
Scope	3 Horizon 2020 calls Time horizon covered: 2014 – 2020.

	Number and type of instruments analyzed: 7 IAs Number of projects analysed: 7
Key data sources	H2020 Work Programs & relevant call text Project data from CORDIS & CORDA 7 interviews (1 Thematic Experts, 3 Project Beneficiaries, 3 Policy and programme representatives) Strategic Policy Documents (Transport White Paper, Mobility Strategy)
Links with partnerships	n/a (Topics partly related to EIT Urban Mobility, ENUAC, EMEurope, ENSCC)
Relevant policies	EU Transport White Paper, 2011 Mobility Strategy, 2020 Green Deal Transport Factsheet 2020 New European Urban Mobility Framework, 2021 Sustainable Development Goal 12.1

Table 91. Project information.

Project Acronym	Project Call ID	Topic	Action Type	EC Net Contribution (Euro)	Project Start	Project End
EBSF_2	H2020-MG-2014_TwoStages	MG-3.2-2014	IA	9 995 952 €	01.05.2015	30.04.2018
DESTINATIONS	H2020-MG-2015_TwoStages	MG-5.5a-2015	IA	17 874 948.01 €	01.09.2016	31.05.2021
CIVITAS ECCENTRIC	H2020-MG-2015_TwoStages	MG-5.5a-2015	IA	17 356 347.97€	1.09.2016	30.11.2020
PORTIS	H2020-MG-2015_TwoStages	MG-5.5a-2015	IA	16 376 774.63 €	1.09.2016	30.11.2020
Park4SUMP	H2020-MG-2017-Two-Stages	MG-4.1-2017	IA	3 501 143.75 €	01.09.2018	31.08.2022
CityChangerCargoBike	H2020-MG-2017-Two-Stages	MG-4.1-2017	IA	3 808 645.63 €	01.09.2018	31.07.2022

Handshake	H2020-MG-2017-Two-Stages	MG-4.1-2017	IA	4 859 093.75 €	01.09.2018	31.08.2022

10.5.2. Tables of Horizon 2020 calls analysed

Table 92. H2020 calls analysed.

WP 2014/2015 (Smart, Green and integrated Transport)	MG-3.2-2014 - Advanced bus concepts for increased efficiency MG-5.5a-2015 - Demonstrating and testing innovative solutions for cleaner and better urban transport and mobility
WP 2016/2017 (Smart, Green and integrated Transport)	MG-4.1-2017 - Increasing the take-up and scale-up of innovative solutions to achieve sustainable mobility in urban areas

11. Case study 11: Shifting paradigms - mobility preferences and behaviour

11.1. Summary

Against the background of the strategic objective of SC 4 to make transport more sustainable, there is a need to rethink the incentives for transport users to make more sustainable choices.

The case study looks at innovative concepts to develop a better understanding of individual mobility preferences and of proven policy measures, tools and technology options to reduce road congestion whilst improving mobility and access. It contains actions on walking and cycling, innovative concepts, systems and services towards Mobility as a Service as well as new tools and business models for public transport and car sharing. The project portfolio of selected calls for this case study supported 11 RIA projects with 160 participations and an EU contribution of 33,3 Mio. €. Participation is strongly concentrated in four Member States and the UK.

European cooperation was necessary for the breadth of the pilot case studies in the projects to ensure a geographical mix and different sizes of regions and cities as well as user groups. Particularly important in this case study was the testing of mobility solutions and data collection on-site. The implemented solutions mostly still exist in the cities and regions. Projects also mobilized start-ups to recognize transport poverty and vulnerable groups as a profitable business field and target group. Most of the projects in this case study focused on aspects of non-technical, social innovations related to sustainable mobility. The results of the projects have been relevant to provide guidance on specific topics related to Sustainable Urban Mobility Planning. All projects are contributing small pieces to support sustainable mobility, and all are needed in that way. It's certainly important that they build on one another. The early efforts that the Commission has been making in this field are much appreciated. It was important to look at different solutions, compare them and think about the benefits and pathways of scaling it up. National sources would not have existed for most of the funded projects in this case study. The EU Commission was the only government agency that was at that time at all interested in the questions raised. EU gave political backing and credibility for taking those topics seriously. Not all problems can be solved completely technologically.

11.2. Introduction and overview

11.2.1. Objectives

Against the background of the strategic objective of SC 4 to make transport more sustainable: a resource-efficient transport that respects the environment, there is a need to rethink the incentives for transport users to make more sustainable choices.

New organisational concepts are likely to impact on the planning and management of transport. For example, individual travellers and businesses are starting to collaborate and share transport assets, fundamentally changing the pattern of demand for passenger and freight services. The integration of the different dimensions of transport, including behavioural aspects and the concept of mobility as a service, which response to the maximum possible extent to the user needs, was one of the major goals of the Mobility for Growth Calls.

A clear understanding of individual mobility preferences and the behaviour of specific groups to establish cost-effective (non-vehicle technology-based) strategies and measures is necessary for more sustainable choices. It includes walking, cycling, public transport and shared / collaborative mobility options.

The case study looks at innovative concepts to develop a better understanding of individual mobility preferences and of proven policy measures, tools and technology options to reduce road congestion whilst improving mobility and access. It contains actions on walking and cycling, innovative concepts, systems and services towards Mobility as a Service as well as new tools and business models for public transport and car sharing. Research topics within this case study seek to provide comprehensive analyses of the dynamics of new preferences, behaviours and lifestyles and the factors influencing them.

It is the objective of this case study to investigate how far Horizon 2020 is addressing this complex set of questions. It will do this by analysing the Logic Model set out in the main report by outcome pathway and provide responses to the relevant evaluation questions. However, it has to be noted that this case study is based on a small number of projects, and the analysis is of a qualitative nature. While robust in approach, it can only refer to the projects included.

11.2.2. Methodology and case study structure

The analytical approach commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to Sustainable Transport and Mobility (e.g., Transport White Paper 2011, Sustainable And Smart Mobility Strategy Putting European transport on track for the future, 2021). This led to the identification of four areas of interest related to transport and mobility for the Green Transition: a) More sustainable modes of transport, b) More sustainable alternatives (supply side), c) More sustainable choices (demand side), and d) Reducing pollution and risk. The case study Mobility Preferences and Behaviour belongs to area c).

The case study approach includes a literature review to gain a better understanding of more sustainable choices, an overview of the project portfolio in the area by project data and a review of deliverables produced by research teams (output publications). For the identified projects, relevant data (as available from Cordis/eCorda data) has been compiled and analysed, including budget, number of project participants, geographic origin and types of beneficiaries, project type, project results and outputs (publications). For the most relevant actions, this will be complemented by further information from additional sources like project websites. In-depth interviews with 6 beneficiaries and external experts have been carried out. Interviewees in this case study are beneficiaries and project participants from different types of organisations and associations representing stakeholder groups at the national level with European experience.

The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus. For synthesizing the analysis, all data have been triangulated and analyzed with respect to the evaluation questions.

11.3. Synthesis of evidence

11.3.1. Measures, behaviour and preferences for more sustainable choices

Building infrastructure for sustainable mobility is pointless if nobody uses it - that is where mobility management comes in. This concept promotes sustainable mobility and reduces single occupancy car use by challenging and changing travellers' attitudes and behaviour. The case study includes many different approaches and challenges connected with the demand side of a more sustainable choice of mobility solutions.

Significantly reducing urban road congestion and improving the financial and environmental sustainability of urban transport will bring major benefits. This requires an improved understanding of measures to reduce urban road congestion whilst increasing urban accessibility for passengers and freight and contributing to the achievement of broader sustainable urban transport policy objectives. It also requires new thinking and innovative business models and service concepts for public transport, walking and cycling, adapted to increasingly limited public budgets. Special attention needs to be paid to issues related to vulnerable groups of citizens and gender issues.

With the projected growth in transport demand, the current modus operandi in transport supply is deemed unsustainable and generates the need for innovative services that could support seamless mobility and a shift from car ownership to usership. An emerging trend towards this direction is the integration of on-demand modes in conjunction with public transport, leading to the Mobility-as-a-Service (MaaS) concept. MaaS is a user-centric, intelligent mobility distribution model in which users' needs are met via a single platform and are offered by a service provider, the mobility operator. A paradigm change in transportation is expected to take place through mobility as a service, where the service providers could offer travellers easy, flexible, reliable, price-worthy and environmentally sustainable everyday travel, including, for example, public transport, car-sharing and road use. Although activities in this field have been ongoing in some of the EU Member States, at the time of the call, there was no quantifiable evidence of its costs and benefits, as well as its influence on travel patterns and behaviour of the end users. The delivery of such solutions was introducing a new concept at that time, which proved to be further developed and turned out to be quite popular in the market; however, nowadays.

Walking and cycling are often seen from a transport policy perspective as a nice “extra” but have the potential to reduce congestion and are more environmentally friendly. There is a need for a paradigm shift wherein non-motorised transport is placed on an equal footing with motorised modes regarding urban road congestion. It basically comes down to taking walking and cycling seriously as modes of transport. The argument was always if we take space away from cars to give it to walking and cycling, then we're going to increase congestion, and so we won't make any reallocation of space. Behavioural change can only be expected once some sort of change is made to make that behavioural change possible (e.g., making the cycling/walking environment attractive and safe).

Accessibility is a concept used in order to address both travel patterns, attitudes and needs of particular social groups, as well as the mobility needs and transport use characteristics of people living in different types of areas. Consideration of specific geographical factors as well as the mobility needs and capabilities of certain population groups is necessary to obtain a more comprehensive view which will allow the elaboration of organisational or technological measures and transport systems that will improve inclusive mobility and equity and support social innovation in this area.

Car sharing has been gradually developing over the past. New business models and social innovation are likely to emerge fostered by new IT applications. A comprehensive and established assessment of its various impacts in social, economic and environmental terms was missing. Estimates for its future growth potential varied considerably, and so did estimates about the "replacing capacity" of car sharing. Similarly, its effects in reducing congestion, as well as the impact on car manufacturing industries, have not been sufficiently explored.

The current appraisal systems of transport modes are based on cost and time saving when discussing mobility options and preferences. Horizon 2020 wanted to go beyond this kind of traditional approach by assessing the subjective perception of the value of travel time. The people's satisfaction with travel time could have an impact on the transport mode choice towards greener transport modes. The specific research challenges of this topic are to provide comprehensive analyses of these new preferences, behaviours and lifestyles, identify the main factors that influence them and assess their potential economic, social and environmental impact.

11.3.2. Strategic policy priorities

11.3.2.1. European Strategic Objectives

The sustainability of transport systems has been identified as a key area influencing the success of the European Green Deal. As one of the main sources of EU greenhouse gas emissions, the EU has set an ambitious goal to reduce these emissions. The continued dependence on fossil fuels and increases in traffic and congestion in European cities and regions due to increased use of private cars and freight/delivery traffic require a comprehensive and multidisciplinary approach to Research & Innovation in the field of transportation.

Currently, transport emissions account for about a quarter of the EU´s emissions, and therefore, a considerable increase in clean vehicle and green fuel uptake is necessary to achieve the envisioned objectives.[1] Looking at the transport-specific policy goals, some key priorities are also outlined in the EU Urban Mobility Framework.[2] For the topic of this case study, the following priorities are especially relevant:

- Attractive public transport services, supported by a multimodal approach and by digitalisation
- Healthier and safer mobility; a renewed focus on walking, cycling and micro-mobility
- Digitalisation, innovation and new mobility services

According to the Sustainable Smart Mobility Strategy (2020), all modes of transportation need to be more sustainable and therefore need to be decarbonized.[3] Regarding the Sustainable and Smart Mobility Strategy, the topic of this case study relates to Flagship 3 (Making interurban and urban mobility more sustainable and healthy) and, to some extent, to Flagship 9 (Making mobility fair and just for all).

11.3.2.2. United Nations: SDGs

Goal n.12 of the 2030 Agenda for Sustainable Development aims to ensure sustainable consumption and production patterns. Transportation and mobility is one of the priority consumption areas. Mobility management programmes encourage people to use more sustainable forms of transportation through personalized communication, incentives, and/or using marketing techniques targeted at personal travel behaviour.

11.3.3. Horizon 2020 programming related to the case study topic

The specific challenges set out in the work programmes 2014/205 as well as 2016/2017 (Smart green and integrated transport), as well as the expected impact of the relevant calls, are reproduced in the following table. Horizon 2020 R&I topics in these calls are well aligned with the policy priorities as described in section 2.2 above.

Table 93. Specific challenges and expected impact of H2020 calls covered in the case study.

H2020 call	Specific Challenge	Expected Impact
MG-5.3-2014 Tackling urban road congestion[4]	Reducing urban road congestion and improving the financial and environmental sustainability of urban transport requires – improved understanding of measures to reduce urban road congestion – increasing urban accessibility for passengers and freight – contribution to the achievement of broader sustainable urban transport policy objectives – new thinking and innovative business models and service concepts for public transport, walking and (safe) cycling – attention to issues related to vulnerable groups of citizens and gender issues.	improved understanding of proven policy measures and tools, and technology options contribution to a significant reduction of congestion improving mobility and access. insights on the feasibility of new public transport business models with long-term financial sustainability insights on impacts, success factors and benefits of walking and cycling Clear commitments from participants and leadership for an ambitious Europe-wide take up and rollout of results during and following the projects
MG-6.1-2016 Innovative concepts, systems and services towards 'mobility as a service[5]	– Advanced capabilities of the transport system across national boundaries and transport modes to respond to multiple users' needs and enable improved travel performance – Analysis and development of coherent concepts encompassing all relevant elements, systems and services to bring Europe's transport system towards a more user-centric, digital and intelligent mobility model – offering travellers easy, flexible, reliable, price-worthy and environmentally sustainable everyday travel – Although ongoing activities in this field, there is no quantifiable	Advanced, cross-border, multi-modal travel planning and booking/ticketing for today's needs, as well as identification of future framework requirements, including socially responsible behaviour, fostering sustainable development and social inclusion. Proof of concepts, including demonstrations, testing and development of private-public collaboration, supported by appropriate technological systems and services. Novel business models for (large scale) deployment of innovative intermodal/ integrated mobility concept(s) and services, including service definition(s), organisational structure/value chain, financial framework and technology harmonisation. The participation of SMEs with proven

	evidence on its costs and benefits, as well as on its influence on travel patterns and behaviour of the end users.	experience in these areas is encouraged.
MG-8.4-2017 Improving accessibility, inclusive mobility and equity: new tools and business models for public transport in prioritised areas[6]	– Accessibility is a concept used in order to address both travel patterns, attitudes and needs of particular social groups, as well as the mobility needs and transport use characteristics of people living in different types of areas. – A more comprehensive view will allow the elaboration of measures and transport systems that will improve inclusive mobility and equity – Incorporation of specific geographical factors as well as the mobility needs and capabilities of particular population groups – The main challenge is to examine whether organisational, technological (including extended use of ICT), and social innovations in public transport can lead to improved accessibility, inclusive mobility and equity in prioritised areas by responding better to their specific needs and demographic/socio-economic characteristics.	The identification and critical assessment of sustainable and inclusive mobility options for European citizens and residents in prioritised areas and improved accessibility offered by public transport systems. The development of effective, efficient and affordable mobility solutions which respond to the specific needs of particular population groups, such as vulnerable to exclusion citizens, taking into consideration the gender aspect. The elaboration of new business models for public transport, with the deployment of organisational, technological (such as IT and app-oriented services) and social innovations taking into account possible social and demographic barriers for their effective use.
MG-8.5-2017 Shifting paradigms: Exploring the dynamics of individual preferences, behaviours and lifestyles influencing travel and mobility choices[7]	Missing comprehensive and established assessment of the various impacts of car sharing in social, economic and environmental terms. Varying estimates for its growth potential as well as the "replacing capacity" of car sharing and its effects in reducing congestion, emissions and noise Impact of car sharing on car manufacturing industries Travel time savings are often seen as the principal benefit of a transportation project, and efforts to achieve faster travel have been long dominating decision making. However, as technology evolves, people can use their time during travel for business or leisure, thus allowing other considerations (such as energy savings, pricing, environmental and social considerations) to affect their travel time preferences.	Comprehensive analyses of the dynamics of new preferences, behaviours and lifestyles to identify the main factors that influence them and to assess their potential economic, social and environmental (including climate) impact. Up-to-date information on the present state of development of new business models and social innovations, a reliable assessment of their growth potential across different geographical cultural and economic environments and an assessment of their impact in areas of key policy interest, such as urban congestion, emission and noise reductions. Generation of new knowledge about users' attitudes and choices with respect to travel time Impact on different cost-benefit assessment methods of transport projects as well as re-organisation of transport routes and schedules based on different perceptions of the value of travel time

11.3.3.1. Project portfolio characteristics

The project portfolio of selected calls for this case study supported 11 projects with 160 participations in total. EU contribution amounts to 33,3 Mio. €. All projects have been completed by 2020 at the latest.

Table 94. Type of organisations in Case Study 11 Shifting paradigms – Mobility Preferences and Behaviour.

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1000)
		Nb	Share (%)	EUR (1000)	Share (%)	
HES	11	23	14%	6.182	19%	268,8
OTH	10	26	16%	4.134	12%	159,0
PRC	11	73	46%	16.195	49%	221,9
PUB	8	22	14%	3.381	10%	153,7
REC	8	16	10%	3.430	10%	214,4
Total (All types)	**11**	**160**	**100%**	**33.323**	**100%**	**208,3**

HES: Higher or Secondary Education Establishments

PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)

REC: Research Organisations

PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)

OTH: Other

Source: eCorda, own calculation.

About half of the EU contributions and projects in this case study went to private for-profit entities. The other types of organisations accounted for roughly equal shares, with universities receiving the second largest share of EC contribution (19 %). Compared with all other Green Transition areas, the portfolio of transport projects has the highest share of funding for private companies (62% in the SC 4 vs 47% in all Green Transition areas). In this case study, the proportion of enterprises is somewhat smaller than otherwise in the transport area.

This case study covers only Research & Innovation Actions (RIA). The projects focus on activities that aim to "…establish new knowledge and/or to explore the feasibility of a new or improved technology, product, process, service or solution"[8].

Table 95. Group of countries of the Case study 11 Shifting paradigms – Mobility Preferences and Behaviour.

Group of country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Number of countries
		Nb	Share (%)	EUR (1,000)	Share (%)		
H2020-EU27	11	132	82.5%	27,704	83.1%	209.9	22
EU-14	*11*	*113*	*70.6%*	*25,609*	*76.9%*	*226.6*	*14*
EU-13	*9*	*19*	*11.9%*	*2,096*	*6.3%*	*110.3*	*8*
H2020-associated (exclude UK)	4	6	3.8%	535	1.6%	89.2	5
United Kingdom	9	21	13.1%	4,961	14.9%	236.2	1
Third Countries	1	1	0.6%	122	0.4%	122.2	1
All-countries	**11**	**160**	**100.0%**	**33,323**	**100.0%**	**208.3**	**29**

Source: eCorda, own calculation.

The EU-14 account for 70 % of participation and three-quarters of the budget in this case study. The eCorda statistics show that although Horizon 2020 opened up the participation of associated countries and third countries, in this case study associated countries (excluding the UK) are representing only a total of 3,8% of participations and 1,6% of EC contribution. Associated countries (Switzerland, Norway, Turkey, Serbia and North Macedonia in this case study) have participated in 4 out of 11 projects and third countries in only one project (Jordan in CREATE). In contrast, the UK participated in most projects (9 from 11). The total budget for participants from the UK represents 14,9% of all EU contributions, which is higher than for EU-13 (6,3 %). Comparing the case study to SC 4 in total (8% of participation, 9% of budget), the participation of the UK is also significantly higher. Participation of Eastern European countries (EU-13) with only 6 % of the budget is in the topics of this case study somewhat underrepresented but higher than in SC 4 total (8% of participation and 4% of budget).

Table 96. Top countries in Case study 11 Shifting paradigms – Mobility Preferences and behaviour.

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Order
		Nb	Share (%)	EUR (1,000)	Share (%)		
Belgium	11	20	12.5%	4,548	14%	227.4	1
Italy	10	20	12.5%	4,952	15%	247.6	2
United Kingdom	9	21	13.1%	4,961	15%	236.2	3
Germany	8	18	11.3%	4,191	13%	232.8	4
France	5	6	3.8%	879	3%	146.4	5
Netherlands	4	7	4.4%	1,535	5%	219.2	6
Portugal	4	8	5.0%	1,981	6%	247.6	7
Greece	4	11	6.9%	3,181	10%	289.2	8
Spain	3	6	3.8%	1,279	4%	213.2	9
Hungary	3	6	3.8%	619	2%	103.2	10
Luxembourg	3	5	3.1%	1,315	4%	263.1	11
Romania	3	4	2.5%	349	1%	87.2	12
Finland	2	2	1.3%	235	1%	117.6	13
Czechia	2	2	1.3%	362	1%	181.0	14
Bulgaria	2	2	1.3%	207	1%	103.7	15
Sweden	2	5	3.1%	665	2%	133.0	16
Switzerland	2	2	1.3%	214	1%	107.0	17
Austria	2	2	1.3%	366	1%	183.2	18

Source: eCorda, own calculation.

Moreover, the participation in this case study is strongly concentrated in only four Member States and the UK, which account for two-thirds of the EU contribution. Participants from Belgium participated in all projects, and participants from Italy in ten of 11 projects. Project coordinators came mostly from Italy (4 of 11 projects) and the UK (2 of 11 projects). Apart from a Slovakian coordinator, all coordinators came from EU-14 or UK.

The network analysis based on the number of collaborations among organisations from each pair of countries in the projects included in this case study confirms a high level of collaboration among a few core countries (Germany, UK, Belgium and Italy), collaborating to a large extent among themselves with the UK being an important player in this group.

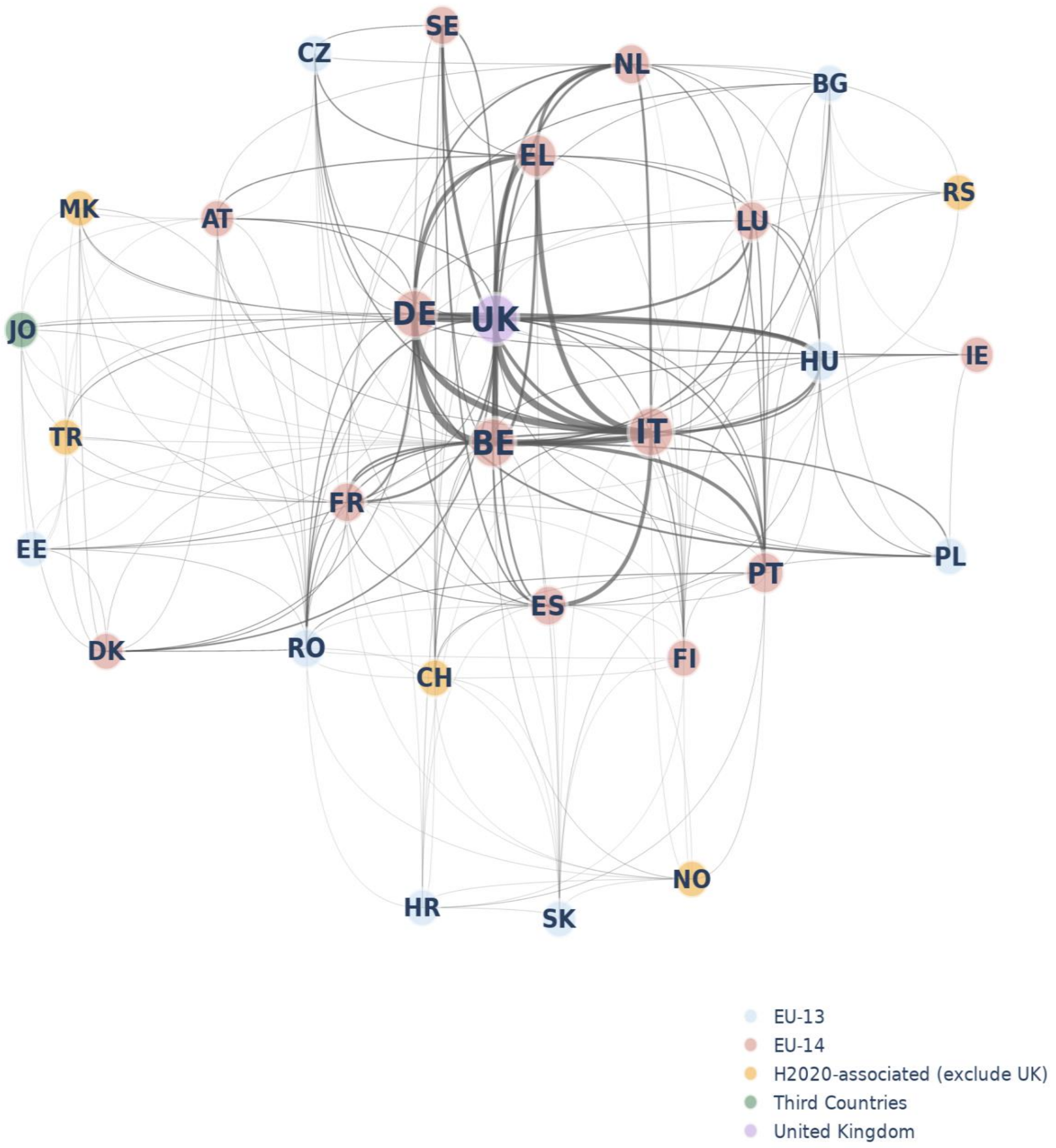


Figure 243 Network of participating countries in case study 11 Shifting paradigms – Mobility Preferences and Behaviour.

Source: eCorda, own calculation

11.3.3.2. European Partnerships related to this case study

The case study does not contain projects funded by European partnerships. The interviews and desk research within this case study could also not discover a relationship at the project level to individually funded projects of ERA-Net Cofunds dealing with urban mobility (e.g., EMEurope, ENUAC, ENSCC). EIT Urban Mobility used some material from FLOW about cycling and walking for its own successful online course.

11.3.4. Results of the Horizon 2020 funding activities: pathways to impact

Already Horizon 2020 and its Work Programmes aimed to contribute to a green transition. The analysis of the Work Programmes and the projects showed that distinct pathways to impact can be identified that connect the activities carried out within the work programme with identifiable effects (outcomes). Based upon the Work Programme analysis, Figure 263 provides an overview of pathways to impact identified in the analysis regarding transport and mobility.

Coordination & Collaboration	Knowledge & Capacity	Market & Business	Technology & Innovation	Policy & Standards
• Stronger pan-European collaboration across disciplines, sectors, value chains and technology levels • Cross-border and cross-sector coordination and integration of R&I efforts	• Better understanding of local and regional specificities, user behaviour and perceptions • New European multimodal transport management systems • More service oriented transport System • Access to new knowledge	• More competitive and cooperative Industry • Access to new Markets • More sustainable manufacturing of innovative systems and equipment	• Comprehensive, intermodal and appropriate systemic solutions • New European Information and payment systems • New generation of innovative and environmentally friendly air, waterborne and land transport means • Efficient interfaces between long distance and urban mobility networks	• More informed transport policies • New transport standards

Figure 244 Expected Outcomes in SC 4.

11.3.4.1. Coordination & Collaboration Pathway

The **coordination & collaboration** pathway highlights the increasing importance of collaboration between different stakeholders (from researchers to regional authorities and transport companies), research disciplines and geographical extent.

European cooperation was necessary for the breadth of the pilot case studies in the projects to ensure a geographical mix and different sizes of regions and cities. This also applies to the broad involvement of different types of beneficiaries (research, consultancy, ICT service providers, municipal administrations, transport operators, start-ups, etc) or user groups. Different transport user groups, their preferences and capabilities for using mobility options have been very much the focus of research. In a small number of projects, cross-border transport cooperation (e.g., in Greater Luxemburg) was essential. Cooperation with third countries did not play a role in the projects analysed.

The market development for car sharing as well as MaaS was more advanced in certain member states and regions than elsewhere in Europe. The European projects enabled an intensive exchange and mutual learning between practitioners and universities of experienced and new-coming regions.

Most projects had established contacts with relevant projects in the same call, shared experience and results in joint conferences, workshops or exhibition stands. Horizon projects launched later were able to tie in with the results, e.g., focus on little-researched user groups. In contrast, there was no mutual influence on the research approach or data collection of projects started in parallel.

MotiV (research about the value of travel time) was the first Horizon 2020 project with a Slovakian University as a Coordinator. Following the success of the project, knowledge and infrastructure for international projects have been created at the university. This allows the successful participation of Slovakia in further projects.

"... *none of the universities in Slovakia could be the coordinator of the Horizon 2020 project or other funding programs in the past. So MoTIV was kind of a milestone for the whole University and the Research Center. And university management is quite proud that they were the first University in Slovakia."* (Beneficiary)

CIVITAS is a network of cities for cities dedicated to cleaner, better transport in Europe and beyond. The Commission launched a reinvigorated CIVITAS 2020 Initiative under Horizon 2020. Some of the projects (FLOW, TRACE, CREATE, CIPTEC) were involved in the CIVITAS Initiative, and they brought the lessons learned into the exchange between the cities.

11.3.4.2. Knowledge & Capacity Building Pathway

The **knowledge & capacity**-building pathway emphasizes a better understanding of local and regional specificities, user behaviour and perceptions. Furthermore, it asks for a more service-oriented transport system and new access to knowledge, contributing to the creation of capacities for the uptake of transport solutions, for example, in public authorities.

Particularly important in this case study was the testing of mobility solutions and data collection on-site. The public authorities, cities and regions benefited from the exchange with the scientific community based on the latest research results on which the design of the mobility solutions was based. On the other hand, the test results, impacts and experiences fed the development of the solutions on the researchers' side. In this way, the projects also helped to fill in missing knowledge of public authorities, including the impact of sustainable mobility measures and state-of-the-art data collection, interpretation, and transport modelling.

11.3.4.3. Market & Business Pathway

The **market & business** pathway emphasizes greater involvement of public and private actors and a focus on pilot and demonstration activities to assess solutions in practice and to follow a need and demand-driven approach. The marketability and feasibility of solutions should be supported to generate interest among market actors. Demonstration and pilot activities should facilitate replication, upscaling, and new business models.

Apart from the outcomes regarding research, several projects introduced new mobility solutions in pilot regions. The solutions mostly still exist in the cities and regions.

Projects mobilized social impact start-ups to recognize transport poverty and vulnerable groups as a profitable business field and target group, thus supporting social impact start-ups as new market participants/innovators in transport. Most of the start-ups (9 from 10) have grown after the project ended and survived until today.

From the analyses of the satisfaction factors, indications can be derived for public transport operators with regard to more comfort and the use of ICT in the means of transport.

11.3.4.4. Technology & Innovation Pathway

The **technology & innovation** pathway emphasizes the importance of comprehensive, intermodal and appropriate systemic solutions. This involves the deployment of a portfolio of solutions as part of a new system or their deployment and integration into an existing system with associated improvements in the services that these sectors provide.

The projects in this case study topic are only partly focused on the development of technological innovations. Technological solutions were particularly focused on the development of MaaS architectures or the further development of transport modelling. The other projects focused on aspects of non-technical, social innovations related to sustainable mobility.

Now, transport model providers are recognizing the need for cycling/walking in macroscopic or microscopic modelling and also advising cities accordingly regarding its effects. It improves existing transport analysis techniques and models to include all modes and to account for the interaction among modes (FLOW). The FLOW Multimodal Transport Analysis Methodology uses Key Performance Indicators (KPIs) to operationalise its multimodal definition of transport network performance and congestion in terms of travel time and the relationship between the demand for and supply of road space.

The project MaaS4EU was a successful first step in answering some of the core questions about MaaS architecture. Three different organizational structures for MaaS have been explored, describing different frameworks through which a MaaS system can be arranged, operated and developed. Trials of the MaaS application demonstrated to provide a successful solution.

IMOVE research and innovation action was based on the investigation, development and validation of bottom-up novel solutions able to define sound MaaS business models, smoothing their efficient and profitable service operation. A suite of ITS elements empowering MaaS schemes was delivered by IMOVE, including technology components for real-time collection of fine-grained data on mobility user needs, habits and preferences, as well as components enabling the exchange of information and enhancing seamless interoperability among different MaaS subsystems and multiple MaaS schemes.

MyCorridor achieved to develop a one-stop-shop standards-abiding MaaS platform that allows, through mobile applications, travellers to experience a series of mobility, infomobility and value-added services under the MaaS paradigm. Its overall objective was to achieve sustainable travel in urban and interurban areas and across borders by replacing private vehicle ownership with private vehicle use. The project investigated connecting services from various service providers and providing the traveller with alternatives to replace their own vehicle trip with combined shared vehicles and multimodal transport solutions. Service providers and other MaaS aggregators interfaced their services or the platforms through it in a cross-border fashion. The technical solution was supported by novel business roles and relations, personalised services and single-access payment and tokens for the trips.

TRACE assessed the potential of mobile-based tracking services for cycling and walking to optimise the planning and implementation of such measures and enhance their attractiveness and potential impact. The end results were common, flexible and open-access tools that can be developed into tracking service products tailored to the needs of specific measures. Other projects relied on developing and utilising modern marketing techniques and co-creation workshops to better understand and attract new users for public transport at as low a cost as possible (CIPTEC). CREATE studied how cities in Western Europe tackled growing car use and congestion over 50-60 years as a basis for drawing lessons for a faster reduction in car use and towards the use of more sustainable transport modes.

11.3.4.5. Policy & Standards Pathway

Finally, the **policy and standards** pathway focuses on more informed transport policies and new transport standards.

The pilots have been embedded in local strategies, such as sustainable urban mobility plans or municipal or regional climate protection concepts and thus contributed to the implementation of concrete measures on the ground. The scientific monitoring and evaluation of the projects supported policy learning and the improvement of the concepts. Analysis of patterns of success and failure in case studies led to principles for mobility solutions and quick facts for mobility planners and municipal authorities.

The results of the projects have also been relevant to provide guidance on specific topics related to Sustainable Urban Mobility Planning (SUMP), as outlined by the European Commission’s Urban Mobility Package[9] and described in detail in the European SUMP Guidelines[10] (Second edition 2019). This mainly concerns the role of cycling and walking, MaaS and shared mobility. The results of the projects were incorporated into the formulation of some of the guidelines.[11] Where relevant, almost all projects also analysed the regulatory framework for the solutions developed and made suggestions for improvement.

The project FLOW has contributed to the serious integration of cycling/walking in transport models. Thus, the R&D is contributing to a recognition of its potential to reduce congestion in cities and to make better informed political decisions.

“I think that we have put all these projects together also to learn about prerequisites of behavioural change. Not only is it directly connected, but I know that the modelling exercise is just the basis for information for politicians at first, and then something has to happen on the ground regarding infrastructure, cycling or whatever.” (Expert)

The MaaS projects (MyCorridor, MaaS4EU, IMOVE) were successful in creating a fruitful relationship with the MaaS Alliance[12], which led to a joint effort to explore a common MaaS API. This collaboration aims at streamlining the currently cumbersome and time-consuming API integration process of the various transport services. In alignment with the collaboration with MaaS Alliance, the projects are participating and contributing to the standardization initiatives beyond the end of the projects.

An evaluation standard for car-sharing solutions in German cities has been developed based on the STARS project. The results of this project also fed into a National Development Plan for Car-Sharing (Germany).

11.4. Conclusions

EQ 4.1: What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects’ results all together leading to the achievement of the programme’s objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

Regarding the climate targets in transport, a significant reduction of emissions can only be achieved by a significant reduction in car traffic and a shift of routes to other means of transport. With this in mind, it is absolutely crucial to look at all the instruments that could possibly contribute to this necessary reduction. In this respect, the question was very proactive at the time. The research helped to look at different transport transformation tools and approaches, mostly for the first time in Europe-wide research.

The case study includes many different approaches dealing with the demand side of a more sustainable choice of mobility solutions. On the one hand, the preferences and possible incentives of users in different contexts and regions are investigated. On the other hand, the conditions that enable better transport choices are concretely improved through pilot projects in cities and regions.

All projects are contributing small pieces, and all are needed in that way. It's certainly important that they build on one another. The early efforts that the Commission has been making in this field are much appreciated. It was important to look at different solutions, compare them and think about the benefits and pathways of scaling them up.

For the more experienced or specialized project partners, the existing knowledge was confirmed and deepened (e.g., an overview of the state of car-sharing products in Europe). It was possible to do international comparative studies. The maturity of the markets and framework conditions of the different approaches varied greatly when the projects were launched in Europe. The differences have been elaborated in the studies and contributed to a more realistic view of it.

Apart from the outcomes regarding research, several projects introduced new mobility solutions in pilot regions. The solutions mostly still exist in the cities and regions. They have been partially revised or adapted according to the experience from the pilot case studies but are still active. In some cases, the introduced or suggested pilot mobility solution or approach was an early starting point for still ongoing improvements in the city (e.g., redistribution of space between motorized and non-motorized transport modes). Another project mobilized, taught possible founders and supported social impact start-ups to address transport poverty and mobility solutions for vulnerable users as a profitable business case. Most of the start-ups (9 from 10) have grown after the project ended and survived until today.

EQ 4.2: Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact?

Success factors

International cooperation was necessary for the breadth of the pilot case studies in the projects to ensure a geographical mix and different sizes of regions and cities.

It was important that experienced project partners were represented in the team who knew the current state of knowledge. This enabled the newcomers to learn quickly. This was all the more true in cases where the market development was in some countries far ahead of the other member states (e.g., car sharing, MaaS).

In those projects that implemented concrete mobility options in pilot projects or via start-ups, the motivation in the team for social impact was very high.

Much experience with H2020 project management in detail with the consortium leader was an important success factor. A massive network and careful selection of partners are needed to establish an appropriate well-balanced consortium. The progress during the project should be continuously monitored. The ability of the coordinator to communicate with partners and appropriate time planning for tasks (e.g., data collection and app development) is also crucial.

Barriers

It is the task of the regional authorities to take action and make changes regarding mobility choices happen. In several pilot cases, the project was sort of an early push. A challenge is also a changing political environment for projects in cities. It is problematic when political priorities change in municipal projects, and then projects cannot be implemented as planned or disappear from the agenda (thus, the potential impact is hindered). During a MaaS project, e.g., Luxemburg decided to offer public transport for free (early 2020). This meant that cross-border ticketing systems were no longer a high priority in this region. Parallel political developments and priorities, more important projects at the local level and resulting conflicts of interest can affect the success of projects.

In general, requirements and prerequisites for behaviour change and related communication should be considered. A stakeholder engagement consultation and sustainable mobility planning processes take time. Those conversations over the long term are an ongoing task to enable municipal decisions and real changes on the ground.

Technical experience with mobility options is needed at the city level. But the education of planners about cycling is still missing at universities. Most planners are learning this on the job only.

Developing a Horizon 2020 proposal is a big investment and a challenging task. There are also many bureaucratic hurdles during the project period (e.g., exit or change in the legal form of partners) that can affect the progress of the project. This forms a barrier to participation. Projects also reported a lack of quick feedback on administrative or financial issues but also on the content of the reports from project officers. Some projects lacked support for the project coordinator (which has no intervention options vis-à-vis partners) from the project officer when a partner did not fulfil its commitments in an appropriate manner, quality or scope.

The common language English is also an issue for participation, especially in smaller cities.

In some projects, which have not finalized field work before 2020, the Corona crisis had a deep impact on pilots. The usage of public transport was considerably disturbed (lower number of users). This led partly to virtual pilots that could not fully realise their potential.

In some cases, there was no time in the project for more detailed scenarios for scaling up specific solutions (e.g., car sharing). This is one of the reasons why the direct outcome of such projects is implemented in a limited way.

There are no open calls in Horizon so far. If one would like to come up with good ideas, now the idea waits for the appropriate call and is then adapted. The calls in H2020 / Horizon Europe are created after a participatory process under the assumption that the good ideas are then known by the Commission. However, this does not cover everything. In addition, there is the "political influence" and overburdening with additional topics. Calls should not "piggyback" on so many political topics ("camel call" with humps). The coherence of the call and of the submitted projects suffers from this.

Longer duration of projects (4-5 years) would be better because then one can allow more time for the mobility solutions to pass until the impact evaluation. Mobility patterns do not change that quickly. Participatory processes regarding the implementation of mobility solutions also take longer because one must build trust first. The project runtimes are too short for both (impact assessment after implementation of mobility solutions too early and necessary stakeholder participation before implementation).

E.Q. 4.3: To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts?

There are strong incentives on the part of the Commission to communicate the results and messages to the outside world. This led to a standardisation of communication activities in all projects, mainly doing the same (Websites, social media, newsletters, conferences). There are specialised communication professionals who basically deal with it on an assembly line. From today's perspective, the projects did everything necessary for dissemination and reached their target groups. The measures are different in terms of reach: conferences reach few target groups but then intensively; in contrast, flyers reach many people without intensive interaction. However, most of the projects used standards but were not particularly creative. A lot of marketing effort went into appearances on social media, only to find a few followers there. Indicators for outreach are difficult to assess. Today, projects would also create more videos or podcasts according to their own assessment. A special topic for most projects was to reach out to specific groups of users to participate in data collection or to test mobility solutions. Dissemination activities towards start-ups and the start-up ecosystem in some projects were very successful and can therefore be particularly highlighted.

The established profile on social media, as well as project websites, are no longer populated with content after the end of the project. Therefore its long-term benefits are questionable. The result is a jumble of different project websites, which are difficult to access. The Cordis website with the project results has an outdated design, does not contain all results and is not sufficiently known even among project partners.

It was generally a problem that the public relations work was required to be very directly linked to the production of the results. So, the results were produced, and in the same breath, it was already a question of how to communicate this and reach the public: What formats, what are the messages? Sometimes the transport scientists were overwhelmed with the task of quickly translating this into messages. It would have needed time to qualify the results, but there was too much time pressure. Thus, the communication was mainly based on what was already known. The messages were developed under the immediate impression of the results. But a little more processing would have been necessary. Thinking about the potential for improvement regarding mobility options, the main issue is that between the results and the appearance of the message, there is a bit of time for reflection. In the projects, more time should be set aside to convey that.

The physical distancing rules during the Corona crisis led to a switch of resources to online dissemination activities instead of printed matter or meetings in person; probably, a larger audience was reached this way. For the projects under consideration, however, the fireworks of final conferences were impaired at the end of the project because public attention was also focused on other issues.

Learning courses for cities reached quite a good group (general context of mobility options for cities, modelling of expected results, political issues). It was considered more effective than general dissemination. Quick facts for policymakers are most important for dissemination. Online courses are now more important for a wider audience, also shorter bite-size inputs by reusing content. To reach out to not involved cities, apart from a core group of already active cities, remains a challenge.

EQ 4.4: To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The results of the projects have been relevant to provide guidance on specific topics related to Sustainable Urban Mobility Planning (SUMP), as outlined by the European Commission's Urban Mobility Package[13] and described in detail in the European SUMP Guidelines[14] (second edition 2019). This mainly concerns the role of cycling and walking, MaaS and shared mobility.[15] Sustainable Urban Mobility Planning is a strategic and integrated approach to dealing with the complexity of urban transport. Its core goal is to improve accessibility and quality of life by achieving a shift towards sustainable mobility. SUMP advocates for fact-based decision-making guided by a long-term vision for sustainable mobility. As key components, this requires a thorough assessment of the current situation and future trends, a widely supported common vision with strategic objectives, and an integrated set of regulatory, promotional, financial, technical and infrastructure measures to deliver the objectives.

SDG 12.1 Sustainable Consumption and production patterns are the relevant, sustainable goal, especially regarding sustainable mobility. All projects contribute to this by implementing mobility solutions, supporting more sustainable choices and understanding user behaviour.

EQ 5.1. What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

For the topic of car sharing, cycling and walking as well as MaaS, the European Commission was an early pioneer in addressing this topic in a research programme. National sources would not have existed for most of the funded projects in this case study. The EU Commission was the only owner of public R&I funding that was at that time at all interested in the questions raised. EU gave political backing and credibility for taking those topics seriously. The Commission's initiative has greatly accelerated the establishment of MaaS approaches.

Without H2020, most of the projects would absolutely not have been feasible. There is no substitute for international exchange, ensuring greater coverage of a European dimension of research. This is especially true for the diversity of case studies, mobility approaches and partners. It is important for social cohesion that Europe grows together through a network of people. An important added value was that European funding made larger projects (more regions, balance of partners) in European cooperation possible. National funding for the topics concerned was limited or not available at all.

From the perspective of this topic, the technology focus in Horizon 2020 is too one-sided. Social innovation is only mentioned as a subordinate clause compared to technology development. On the other hand, the EU has an interest in commercialisation and technological world leadership. However, not all problems can be solved completely technologically.

11.5. Annexes

11.5.1. Key metadata of the case study no. 11 Shifting paradigms – Mobility Preferences and behaviour

Table 97. Key metadata of case study no. 11 Shifting paradigms – Mobility Preferences and behaviour.

Case no. 11	Shifting paradigms – Mobility Preferences and behaviour
Evaluation Question addressed*	EQ 4.1, 4.2.; 4.3; 4.4.; 5.1.
Area	Sustainable Transport
Programme parts	WP 2014/2015 (Smart, Green and integrated Transport) WP 2016/2017 (Smart, Green and integrated Transport)

Scope	4 Horizon 2020 calls Time horizon covered: 2014 – 2020. Number and type of instruments analyzed: 11 RIAs Number of projects analysed: 11
Key data sources	H2020 Work Programs & relevant call text Project data from CORDIS & CORDA 6 interviews (1 Expert, 6 Project Beneficiaries) Strategic Policy Documents (Transport White Paper, Mobility Strategy)
Links with partnerships	n/a (Topics partly related to EIT Urban Mobility, ENUAC, EMEurope, ENSCC)
Relevant policies	EU Transport White Paper, 2011 Mobility Strategy, 2020 Sustainable Development Goal 12.1

Table 98. Project information.

Project Acronym	Project Call ID	Topic	Action Type	EC Net Contribution (Euro)	Project Start	Project End
TRACE	H2020-MG-2014_TwoStages	MG-5.3-2014	RIA	2.896.984	01.06.2015	31.05.2018
FLOW	H2020-MG-2014_TwoStages	MG-5.3-2014	RIA	3.781.696	01.05.2015	30.04.2018
CIPTEC	H2020-MG-2014_TwoStages	MG-5.3-2014	RIA	3.498.350	01.05.2015	30.04.2018
CREATE	H2020-MG-2014_TwoStages	MG-5.3-2014	RIA	3.870.146	01.06.2015	31.05.2018
MaaS4EU	H2020-MG-2016-Two-Stages	MG-6.1-2016	RIA	3.660.256	01.06.2017	30.10.2020
IMOVE	H2020-MG-2016-Two-Stages	MG-6.1-2016	RIA	3.393.566	01.06.2017	30.11.2019
MyCorridor	H2020-MG-2016-Two-Stages	MG-6.1-2016	RIA	3.491.331	01.06.2017	30.11.2020
HiReach	H2020-MG-2017-SingleStage-INEA	MG-8.4-2017	RIA	2.024.875	01.10.2017	30.09.2020
INCLUSION	H2020-MG-2017-SingleStage-INEA	MG-8.4-2017	RIA	2.969.007	01.10.2017	30.09.2020
STARS	H2020-MG-2017-SingleStage-INEA	MG-8.5-2017	RIA	1.805.665	01.10.2017	31.03.2020
MoTiV	H2020-MG-2017-SingleStage-INEA	MG-8.5-2017	RIA	1.930.835	01.11.2017	31.07.2020

11.5.2. Tables of Horizon 2020 calls analysed

Table 99. H2020 calls analysed.

WP 2014/2015 (Smart, Green and integrated Transport)	Appendix A **MG-5.3-2014 Tackling urban road congestion**
WP 2016/2017 (Smart, Green and integrated Transport)	Appendix B MG-6.1-2016 Innovative concepts, systems and services towards 'mobility as a service Appendix C MG-8.4-2017 Improving accessibility, inclusive mobility and equity: new tools and business models for public transport in prioritised areas Appendix D MG-8.5-2017 Shifting paradigms: Exploring the dynamics of individual preferences, behaviours and lifestyles influencing travel and mobility choices

11.6. References

[1] TEPNIAK, M., GKOUMAS, K., MARQUES, D., GROSSO, M., & PEKAR, F. (2022): Public transport research and innovation in Europe. An assessment based on the Transport Research and Innovation monitoring and Information System (TRIMIS). Publications Office of the European Union: Luxemburg.

[2] European Commission (2021): The New EU Urban Mobility Framework (COM/2021/811 final: European Commission: Belgium.

[3] European Commission (2020): Sustainable and Smart Mobility Strategy – putting European transport on track for the future. COM/2020/789 final. European Commission: Brussels.

[4] Horizon 2020 Work Programme 2014-2015. 11. Smart, green and integrated Transport (Revised), p. 44.

[5] Horizon 2020 Work Programme 2016-2017. 11. Smart, green and integrated Transport (Revised), p. 51f.

[6] Horizon 2020 Work Programme 2016-2017. 11. Smart, green and integrated Transport (Revised), p. 65f.

[7] Horizon 2020 Work Programme 2016-2017. 11. Smart, green and integrated Transport (Revised), p. 67-69.

[8] Definition of RIA as provided in the Commission Staff Working Document In-depth Interim Evaluation of HORIZON 2020.

[9] Annex 1 of COM (2013) 91.

[10] Rupprecht Consult - Forschung & Beratung GmbH (editor), 2019 Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan, Second Edition.

[11] See ERTICO – ITS Europe (editor) (2019): Mobility as a Service (MaaS) and Sustainable Urban Mobility Planning.

[12] https://maas-alliance.eu/

[13] Annex 1 of COM (2013) 91.

[14] Rupprecht Consult - Forschung & Beratung GmbH (editor), 2019 Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan, Second Edition.

[15] See ERTICO – ITS Europe (editor) (2019): Mobility as a Service (MaaS) and Sustainable Urban Mobility Planning.

12. Case study 12: Future transport - Sustainable and Safe for All

12.1. Summary

The case study identifies and analyses relevant actions related to Sustainable and Safe Transport for All in Horizon 2020 and respective partnerships such as Shift2Rail, CCAMM and KIC Urban Mobility. The thematic scope of this case study includes projects addressing safety on the road, rail and waterborne transport.

The case study shows that the work programs have established a portfolio of interventions in the field of Smart, Green and Integrated transport that considers the safety of those participating in transport, be this as drivers, cyclists, pedestrians, railway passengers, train drivers and those onboard water-borne vessels. However, it also highlights that there is more work to be done.

Future Transport: Sustainable and Safe for All was included as a case study in this evaluation which focuses on the Green Transition because of its link to choices made by citizens and businesses. These choices include modal choices and impact directly on CO2 emissions and other environmental outcomes. Only a safe railway system or a railway system perceived as safe will be accepted by its potential users. This acceptance is necessary to enable a shift to greener transport. Similarly, cycle paths, walkways and more efficient driving and logistic systems, such as autonomous vehicles, need to be safe and perceived as safe. Safety is likely to have more influence on choice than environmental concerns.

The case study shows that technology solutions need to be combined with an increased understanding of the interaction between humans and machines, the behavioural incentives which affect choices as well as how to include vulnerable transport users in the safer and greener system. Solutions have to be integrated across Europe because of its integrated transport system and to ensure the Internal Market can function. Solutions also have to be cognizant of the cultural and behavioural differences across the continent.

While most projects achieved their objectives, some were held back by issues arising in project coordination and from the COVID pandemic.

12.2. Introduction and overview

12.2.1. Objectives

The case study identifies and analyses relevant actions related to Sustainable and Safe Transport for All in Horizon 2020.

The main objective of this case study is to analyse to which extent Horizon 2020 actions enabled an effective approach for addressing external effects created by transport, including injuries through accidents. Technologies developed to make transport sustainable also have to address safety concerns. Any technology shift that aims to reduce the pressure on the environment and contribute to the Green Transition has to consider the safety of changes in technology or mode choice as well as the public's perceptions of safety in order to be successful.

It is the objective of this case study to investigate how far Horizon 2020 is addressing this complex set of questions and whether there might be hidden barriers to achieving the Green Transition in transport. It will do this by analysing the Logic Model set out in the main report by outcome pathway and provide responses to the relevant evaluation questions. However, it has to be noted that this case study is based on a small number of projects, and the analysis is of a qualitative nature. While robust in approach, it can only refer to the projects included. It has to be noted that safety is also a component in most other transport-related research projects because changes to vehicles, infrastructure and rules will need to be tested against safety standards.[1]

12.2.2. Methodology and case study structure

The analysis comprised 5 Horizon 2020 calls. The time horizon covered with the analysis is 2014 – 2020. The number and type of instruments analyzed are 8 RIAs and 1 CSA. An overview is provided in the Annex of this case study.

The analytical approach commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to Sustainable and Safe Transport for All (e.g., Transport White Paper 2011, Sustainable And Smart Mobility Strategy Putting European transport on track for the future, 2021). This led to the identification of four areas of interest for the Green Transition: a) More sustainable modes of transport, b) More sustainable alternatives (supply side), c) More sustainable choices (demand side), and d) Reducing pollution and risk. The case study Future Transport: Sustainable and Safe for All is part of the case studies covering area d), with links into the other three areas.

Having identified the 4 main areas of interest for an evaluation of Horizon 2020 with respect to Green Transition in Transport, we then selected relevant project actions in Horizon 2020 based on a keyword search of topics in the work programme. For the identified projects, relevant data as available from Cordis/Corda have been compiled and analyzed and complemented by additional sources like project websites.

In addition to the project data analysis, we performed 6 interviews with relevant stakeholders. The interviewees comprised representatives of thematic experts involved in the European strategic processes, project beneficiaries and transport experts. The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus.

For synthesizing the analysis, we triangulated and analyzed the findings in relation to the evaluation questions using the impact pathways as described in the logic model presented in the main report (see Figure 3 for the expected outcomes).

12.3. Synthesis of evidence

12.3.1. A green transition to a sustainable and safe transport system for all

A sustainable and safe transport system needs to address the environmental impact of each mode of transport as related to the vehicles used, the infrastructure, active users, and those passively engaging with them, such as pedestrians in road traffic. In addition, it needs to consider the transport system as a whole and the modal decisions made when alternative modes of transport are feasible. The level to which different modes of transport are integrated differs between countries. In addition, countries' transport systems are integrated with each other across continents.

Injuries and death

Injuries and death differ significantly between modes of transport. Road traffic is by far the most dangerous. 75 people lose their lives every day on European roads, and 750 are seriously injured[2]. And while fatal accidents have fallen in the last 10 years (see Figure 6 in Annex), they are still high and a concern to national governments.

The numbers of accidents hide distributional factors across countries in the EU as well as the mode of transport used. Considering these in turn:

Within the EU, there are significant differences between countries. Romania, for example, has twice as many road deaths per year (87 per million inhabitants) as the European average (42 per million inhabitants) and 4 times as many as Norway and Sweden (less than 20 per million inhabitants) (see Figure 7 in Annex).

Considering the vulnerability of transport users by mode is important to assess the likelihood of a change in the mode of choice. Pedestrians, cyclists and motorbike users are more likely to die or suffer serious injuries in road accidents than those travelling in cars (see Figure 8 in Annex). This means that the more environmentally friendly modes of transport, in particular walking and cycling, are also the least safe.

Comparing road transport with other modes of transport demonstrates that a shift to rail, for example, could already reduce the death toll significantly by a factor of 25 (see Figure 8 in Annex).[3]

In addition to human loss, the European Transport Safety Council estimates the economic loss caused by road death to be EUR 280bn or 2% of GDP.

The statistics provided here have not considered the safety of waterborne transport. The number of maritime incidents in the artic risking lives and the environment is another concerning safety issue.

Causes of accidents

In many cases, road accidents occur when pedestrians, cyclists or motorbikes interact with cars, lorries or vans. Research by Thomas et al. (2013) shows that over half of all road accidents were caused by interpretation errors, i.e. drivers not interpreting a situation correctly, 44% made observation errors and 37% planning errors.[4] This means that most accidents are caused by human error. In addition, road accidents are the main cause of congestion and resulting delays in cities, leading to loss of productivity and reduction in well-being.[5]

Global comparison

Globally European transport systems are comparatively safe. Most deaths occur in developing countries: “In the WHO [World Health Organisation] Africa region, road traffic fatalities increased from 24.1 per 100,000 population in 2010 to 26.6 per 100,000 population in 2013. Over the same period, road fatality rates in the WHO Europe region improved from 10.3 per 100,000 population to 9.3 per 100,000 population. Road trauma in Africa is expected to worsen further, with fatalities per capita projected to double from 2015 to 2030.”[6] Learning and knowledge transfer from EU Research and Innovation (R&I) are therefore important for other countries.

The role of R&I

Research and innovation can play an important role in improving safety in transport. For example, safety is related to infrastructure, such as the quality of roads, the vehicles in use and the individuals participating in transportation. While the railways are safer than roads, level crossings, where road and rail meet, are still dangerous places where one person is killed and close to one seriously injured every day in Europe.[7]

Technology alone will not solve the safety challenges of transport. According to the interviews conducted and project documents, pursuing pathways towards sustainable and safe transport will require a co-evolvement of technological and social innovations, cooperation between local, regional and national governments with the private sector, large-scale public and private investments in physical infrastructures and the application of technology and a good understanding of what induces a behavioural change of actors.

12.3.2. Strategic policy priorities related to safer transport

12.3.2.1. European Strategic Objectives

Section 2.1 already indicates the challenge for R&I: to reduce fatalities by reducing accidents within each transport mode and enabling a choice for safer transport modes which also support the green transition (i.e. the road to rail). In addition, differences between nations need to be understood and addressed.

Against the background of the strategic role transport plays in European societies and economies (around 9% of GVA and 11m jobs)[8] as well as its contribution to emissions (27%)[9], a transition to a climate neutral transport system that does not compromise on personal safety is important. This will enable further just and sustainable development. Several high-level European policy strategies have been developed in order to facilitate a safe and sustainable transport system[10].

European strategic policy objectives are aligned with the facts and R&I challenges as described above:

Going back to the Transport White Paper of 2011, higher safety standards are included in the vision for a future European Transport system. The White Paper establishes a target of close to zero fatalities in road transport by 2050. In line with this goal, the EU aimed at halving road casualties by 2020. Section 2 shows that this has not been achieved but that the trend is in the right direction. The White Paper also aims for the EU to be a world leader in safety and security in all modes of transport.[11]

Moving on from the White Paper, the Mobility Strategy 2020 made clear that the greening of the transport system and increased safety had to go hand in hand. Many of the technologies which are part of greening can also assist in improved safety – and technologies and innovations will only be accepted if they are perceived as safe. Modal shift and the use of digitalisation are two important contributors to achieving these join objectives:

- Modal shift, for example, to rail away from roads can make an important contribution to both Greening and Safety, as stated in the Council Conclusion "*Putting Rail at the Forefront of Smart and Sustainable Mobility*" in June 2021.[12]

- Digitalisation, as stated in the vision of the strategy: will become an indispensable driver for the modernisation of the entire [transport] system, making it seamless and more efficient.[142,143] Digitalisation and automation can use already existing technologies to further increase the levels of safety, security, reliability, and comfort. By integrating digitalisation into vehicles and infrastructure and developing new designs around them, the EU can maintain its leadership in transport equipment manufacturing and services and improve the EU's global competitiveness through efficient and resilient logistics chains.[144]

Box 1. Strategic direction for safe and smart mobility – Flagships.

Flagship 6 – Making connected and automated multimodal mobility a reality

The EU needs to take full advantage of smart digital solutions and intelligent transport systems (ITS). Connected and automated systems have enormous potential to fundamentally improve the functioning of the whole transport system and contribute to our sustainability and safety goals. …

Europe must seize the opportunities presented by connected, cooperative, and automated mobility (CCAM). CCAM can provide mobility for all, give back valuable time and improve road safety. …

The Commission will explore options to further support safe, smart and sustainable road transport operations under an existing agency or another body.

Flagship 10 - Enhancing transport safety and security

The safety and security of the transport system are paramount and should never be compromised, and the EU should remain a world leader in this field. ….

Europe remains the safest transport region in the world. While air, sea and rail travel are very safe, there is no room for complacency, particularly on road safety.

Source: Mobility Strategy 2020

Two of the 10 Flagships set out in the Mobility Strategy are closely aligned with the safety ambitions set out above.[16] Connected and automated systems play an important role under Flagship 6 of the 2020 Mobility Strategy, making use of the opportunities digitalisation brings to safety. Flagship 10 sets out the ambition of the EU to remain the safest transport region in the world. Box 1 provides more detail on Flagships 6 and 10.

Flagship 6 also highlights the need to address the lack of harmonisation and coordination of relevant traffic rules needs to be addressed to ensure mutual understanding across the EU, avoiding accidents as people move from one country to another.

Maritime Safety

The European Maritime Safety Agency published its latest strategy in 2019. [17] It highlights the opportunities and challenges which digitalisation and artificial intelligence bring to maritime safety. It is EMSA's objective to provide knowledge-based solutions in order to address safety concerns.

12.3.2.2. United Nations, SDGs

Road safety is a global challenge. 93% of the world's fatal road accidents occur in developing countries 1.35 million people die on the world's roads every year, and another 50 million are seriously injured. [18]

Safety in transport, in particular road safety, is addressed in two of the UN's Sustainable Development Goals (SDGs). SDG target 3.6 calls to halve the number of global deaths and injuries from road traffic

[142] Sustainable and Smart Mobility Strategy, Putting European transport on track for the future, 2020

[143] European Commission, Efficient and Green Mobility, IMPROVING ROAD SAFETY AND DRIVER COMFORT through digitalisation, December 2021

[144] Sustainable and Smart Mobility Strategy, Putting European transport on track for the future, 2020

accidents. SDG target 11.2 calls for improving road safety in the provision of access to transport systems and expanding public transport.[19]

In order to address the challenges of road safety at the global level, the UN set up the United Nations Road Safety Fund (UNRSF) in 2018 under SDG 3.6. This fund recognises the significant inequalities in road safety and aims to half fatal accidents in low and middle-income countries.[20] Research and knowledge sharing are part of the tools which can be applied to reduce inequality in road safety.

Summarising, the overall ambition of the existing high-level policy strategies related to a green transition of a safer and sustainable transport system is to use technology such as digitalisation and artificial intelligence in combination with modal shift and behaviour change to reduce fatal accidents and injuries in the transport system.

12.3.3. Horizon 2020 programming related to Future Transport: Sustainable and Safe for All

All three work programmes of SC4 recognise the need for safer transport in all modes, including where different modes of transport meet each other, for example, pedestrians' interaction with cars or cars with trains on level crossings.

This case study is closely related to the work on Sustainable and Smart Cities as well as urban mobility, one of the case studies within SC4. For example, the project InterACT, included in this case study, analyses scenarios of interactions between pedestrians crossing the road and autonomous vehicles driving on urban roads.

Horizon 2020 R&I topics are well aligned with the policy priorities as described in section 2.2 above. They include smart mobility systems, the interface for communication between vehicles and infrastructure, intelligent infrastructure and transport management systems.

The table below summarises the calls analysed in the case study, the specific challenges addressed and the expected impact.

Table 100. H2020 work programme calls, impacts and challenges.

H2020 call	Specific Challenge	Expected Impact
MG.3.5-2014. Cooperative ITS for safe, congestion-free and sustainable mobility	Moving closer to solving problems related to congestion, traffic safety and environmental challenges can be achieved by connecting people, vehicles, infrastructure and businesses into one cooperative ecosystem. Significant technological progress in this area has been made in the past years; however, large-scale deployment is in its infancy.	The establishment of an integrated transport "info-structure", relying on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, but also on the availability of open and quality transport data, will improve transport systems • Safety level, by reducing the number of crashes • Sustainability, by cutting down GHG and other pollutant emissions
MG 3.6 2015 Safe and connected automation in road transport	Automated and progressively autonomous driving applications in road transport, actively interacting with their intelligent environment, could provide an answer to the EU objective of reconciling growing mobility needs with more efficient transport operations, lower environmental impacts and increased road safety.	Projects should contribute to: • Reduction of the automated driving systems' development costs • Enhanced robustness and performance of sensor and data analysis systems • Improved efficiency, safety and traffic flow.
ART 04 2016: Safety and end-user acceptance aspects of road automation in the transition period	The introduction of automated vehicles into the existing traffic poses specific issues regarding safety, in particular during the transition period, where there will be interactions with other vehicles (of any degree of automation or none) and other traffic participants such as pedestrians or cyclists. Automated vehicles will be accepted	Actions are expected to develop safe automated driving systems which are fully in line with user expectations. Actions will provide significant contributions in the following areas: – Reducing the number of accidents caused by human

	by customers and society only when they are deemed easy-to-use and fully reliable, and safe.	errors. – Maintaining the leadership position of the European vehicle manufacturers and their suppliers in this area. – Proper validation procedures for automated driving systems to assess and test functional safety and performance.
MG 3.3 2016: Safer waterborne transport and maritime operations	Heavier and more diverse waterborne traffic needs specific operational knowledge and information management, technology support, as well as advanced vessel and equipment designs that are intrinsically safer and address safety issues holistically. The specific challenge is to build the enabling knowledge, develop designs, technologies, and operational procedures and test them in a real world environment with the aim of guaranteeing safe and environmentally sound waterborne operations.	Activities will improve waterborne safety through proof of concept for new operational and traffic management approaches (including those in extreme environments); through workable goal-based approaches to risk and impact minimisation covering the design and the entire life cycle of vessels; and through a validated safety analysis for fuels with higher intrinsic risks which can be applied in practice. Improved safety is expected to reduce risks for environmental damages linked to accidents in waterborne transport.
MG 3.4 2016 Transport infrastructure innovation to increase the transport system safety at modal and intermodal level (including nodes and interchanges)	Infrastructure plays a vital role in increasing transport safety levels, in particular in road transport. However, many elements of the surface transport infrastructure are in a deteriorating condition due to climate change. Failure to meet infrastructure needs will have drastic consequences for the required functions of a modern network, and will negatively impact on the safety level of the whole European transport system.	Actions will contribute to near eradication of infrastructure-caused accidents increased readability and forgiveness of the transport infrastructure; they will prove the effectiveness of long-term, predictive maintenance systems. The increase of infrastructure safety performance will also contribute to the achievement of sustainable development in the sector and will minimise effects on climate change via the improvement of traffic smoothness.

12.3.3.1. Project portfolio characteristics

The project portfolio of this case study comprises 9 projects all of which have already finished their work.

Table 101. Type of organisations in Case Study Future Transport: Sustainable and Safe for All.

Type of organisation	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1000)	EC contribution Share (%)	EC Contr. per part. (EUR 1000)
HES	9	32	25%	11,182	27%	349.4
OTH	5	9	7%	1,972	5%	219.1
PRC	9	53	41%	16,192	40%	305.5
PUB	4	4	3%	1,305	3%	326.3
REC	8	31	24%	10,296	25%	332.1
Total (All types)	**9**	**129**	**100%**	**40,947**	**100%**	**317.4**

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

Source: eCorda, own calculation.

The sum of EC's net contribution is EUR 41 Mio, of which 40% has been allocated to private companies, 3% to public bodies, 25% to research organisations, 27% to higher education institutions and 11% to other organisations. These shares of funding allocation are roughly equivalent to the number of participations by type of organisation.

Compared with all other Green Transition areas considered in this study (SC1 to SC3 and SC5), the portfolio of transport projects has the highest share of funding for private companies (57% in the SC4 vs 43% in all Green Transition) areas. However, this case study on Safer Transport demonstrates a lower share of private company involvement, 40%, while Higher Education Establishments and Research Organisations show a comparatively strong representation with 27% and 25%, respectively, in this case, the study compared to 13% and 19% in SC4 “Transport” and 19% and 24% in the total.

Table 102. Type of actions/instruments (grouped) in case study Future Transport: Sustainable and Safe for All.

Action/instrument	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)
		Nb	Share (%)	EUR (1,000)	Share (%)	
RIA	8	113	87.6%	38,102.7	93.1%	337.2
CSA	1	16	12.4%	2,844.3	6.9%	177.8
All types	**9**	**129**	**100.0%**	**40,947.0**	**100.0%**	**317.4**

Note: There are no IAs, SMEs or other Actions or Instruments included in this case study.

Source: eCorda, own calculation.

This case study only includes RIAs and CSA, whereby the RIAs take by far the largest share in participation (88%) as well as funding (93%) (see Figure 1).

This focus on activities that either aim to “…establish new knowledge and/or to explore the feasibility of a new or improved technology, product, process, service or solution” is reflected in the projects included in this case study which aim to test whether technology which has been developed is useable within the real world mobility without compromising safety. In this, the RIAs included in this case study focus on the “…testing and validation on a small-scale prototype in a laboratory or simulated environment”.[21]

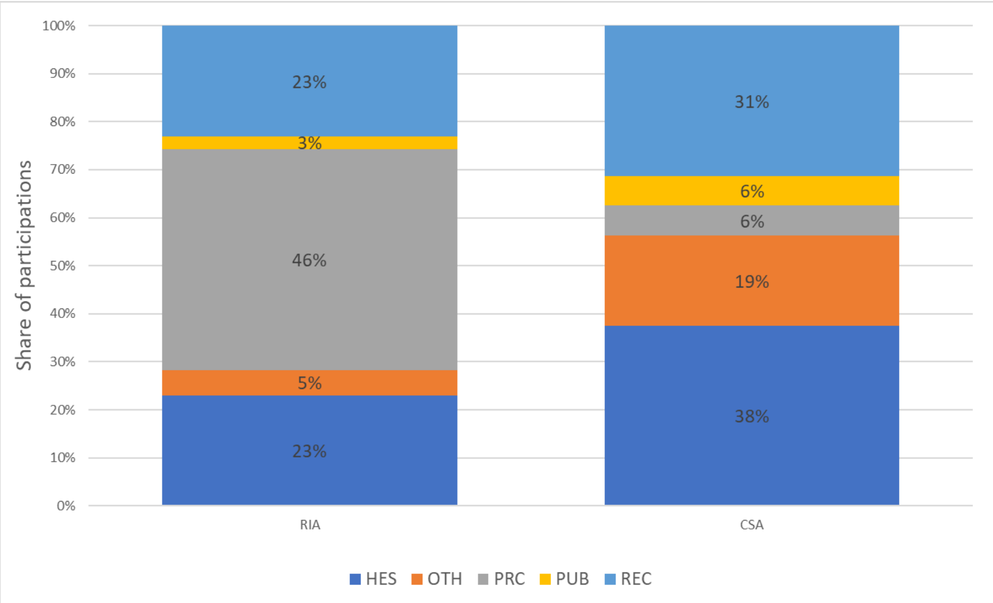


Figure 245 Share (%) of participations by type of action/instruments.

Source: eCorda, own calculation.

The portfolio highlights commitment to innovation and commercialisation of research results (RIA), which have also been confirmed in the interviews with the caveat that private sector participants did not appear to fully engage for commercial confidentiality reasons. The CSA included in the case study has a low share of private participants compared to the RIAs.

Table 103. Group of countries of the case study Future Transport: Sustainable and Safe for All.

Group of country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Number of countries
H2020-EU27	9	100	77.5%	32,463	79.3%	324.6	15
EU-14	*9*	*90*	*69.8%*	*29,844*	*72.9%*	*331.6*	*12*
EU-13	*4*	*10*	*7.8%*	*2,619*	*6.4%*	*261.9*	*3*
H2020-associated (exclude UK)	5	10	7.8%	3,080	7.5%	308.0	4
United Kingdom	6	12	9.3%	5,247	12.8%	437.2	1
Third Countries	3	7	5.4%	158	0.4%	22.5	6
All-countries	**9**	**129**	**100.0%**	**40,947**	**100.0%**	**317.4**	**26**

Source: eCorda, own calculation.

Geographically, the eCorda statistics show that Horizon 2020 opened up the participation of associated countries and third countries, representing a total of 13% of participation. Associated countries (excluding the UK) have participated in 5 out of 9 projects, and third countries in 3 out of 9 projects. However, the total budget for this group represents only 8% of all EU contributions. The largest gap in terms of participation in relation to EC contribution is observed for the EU-13 countries, which participated in 4 projects but received only 6.4 % of the total budget. This is, however, at an equal level with all Horizon 2020 Green Transition projects.

In terms of participation pattern, France, Italy, Germany, and the UK stand out with the highest numbers of participation. In terms of shares of EC contribution in total funding, they received 12%, 16%, 9% and 13% of EC contribution of funding within the case study portfolio. However, in terms of the highest funding per participant, Norway, followed by Germany and Spain, are those with the highest funding. Switzerland, Belgium and Italy are the countries with the lowest EC funding contribution in EUR.

The low rate of participation of EU-13, matched by the high incidence and death rates observed in these countries (see Figure 7), indicates a level of exclusiveness that might be detrimental to utilising the full potential of a transformation of the transport and mobility system across Europe.

Table 104. Top countries in the case study Future Transport: Sustainable and Safe for All.

Top 15 country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Order
Italy	7	14	10.9%	3,783	9%	270.2	1
United Kingdom	6	12	9.3%	5,247	13%	437.2	2
Germany	6	14	10.9%	6,615	16%	472.5	3
Belgium	5	6	4.7%	1,335	3%	222.5	4
France	5	16	12.4%	4,744	12%	296.5	5
Spain	4	7	5.4%	2,672	7%	381.8	6
Greece	4	9	7.0%	2,282	6%	253.6	7
Netherlands	4	5	3.9%	1,580	4%	316.1	8
Sweden	4	5	3.9%	2,342	6%	468.4	9
Finland	3	5	3.9%	1,860	5%	372.0	10
Hungary	2	2	1.6%	575	1%	287.7	11
Austria	2	5	3.9%	1,568	4%	313.6	12
Turkey	2	4	3.1%	1,173	3%	293.3	13
Switzerland	2	2	1.6%	169	0%	84.4	14
Slovenia	2	5	3.9%	1,565	4%	312.9	15
Ireland	2	3	2.3%	942	2%	314.0	16
Norway	2	3	2.3%	1,516	4%	505.4	17

Source: eCorda, own calculation

The network analysis is based on the number of collaborations among organisations from each pair of countries in the projects included in this case study. It confirms a high level of collaboration among a number of core countries, predominantly from the EU-14, collaborating to a large extent among themselves, with the UK being an important player in this group (see **Error! Reference source not found.**).

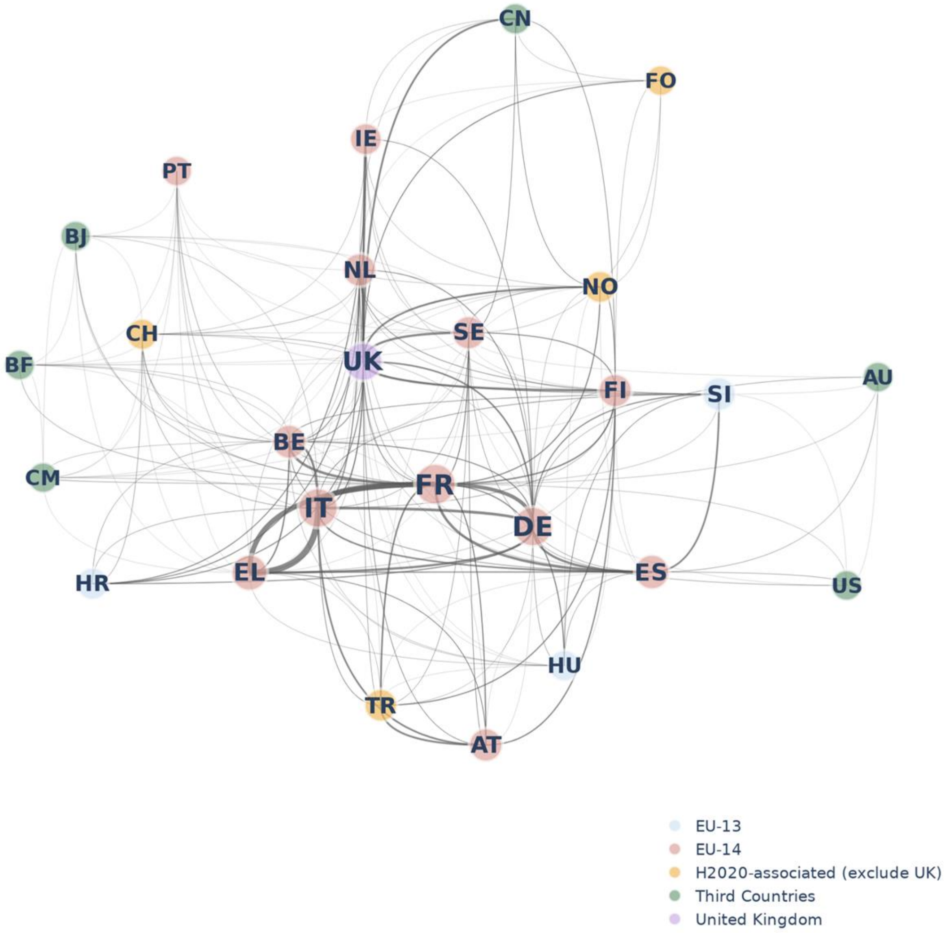


Figure 246 Network of participating countries in Case Future Transport: Sustainable and Safe for All.

Source: eCorda, own calculation.

12.3.3.2. European Partnerships related to Future Transport: Sustainable and Safe for All

In addition to the Horizon 2020 project portfolio and its related calls, three partnerships were considered in this case study: SHIFT2Rail, Connected, Cooperative and Automated Mobility (CCAM) and European Institute of Innovation and Technology (EIT) Urban Mobility. All three are also subject to more in-depth assessment in this evaluation.

The Joint Undertaking (JU) SHIFT2RAIL was set up under Horizon 2020 as the first European research initiative focused on rail in order to develop the technology necessary to enable a Single European Railway Area. SHIFT2RAIL has the vision:

…to deliver, through railway research and innovation, the capabilities to bring about the most sustainable, cost-efficient, high-performing, time-driven, digital and competitive customer-centred transport mode for Europe.[22]

Its first call was published in 2015, and calls have been issued annually since then.[23] SHIFT2RAIL works closely with the European Union Railway Agency, especially when it comes to the safety certification of vehicles. Safety also plays a role in SHIFT2RAIL research activities, for example, traffic management (safe separation of trains), communications between trains and with trains and rail infrastructure. Safety is one of 5 research priority areas, jointly with system integration and interoperability. While safety is addressed in some calls directly (e.g. H2020-S2RJU-2015-01) Integrated Mobility and Safety Management, with 19 topics and a total budget of Euro 43.6m), most calls address other topics.[24] However, safety will always play a role where vehicles, infrastructure and traffic management are affected. It is, therefore, not possible to clearly state the share of the JU's budget allocated to questions of safe transport.

Work by the co-programmed CCAM partnership is of particular relevance for the research related to sustainable and safe transport where vehicle interaction and communication between vehicles and infrastructure is required.[25]

Finally, the EIT's initiative Urban Mobility recognises the need to consider safety in urban transport by addressing it directly in Challenge 4 (C4): *Eco-efficient and safe transport for people and goods, including waste.[26]*

A key publication by this partnership is *Urban Mobility Next #4 Integrated and safe: how innovation can increase micro-mobility end-user adoption.[27]* In this document, the partnership highlights the need to ensure that transport modes are safe and perceived as safe in order to encourage the mode change required to meet the challenges of the Green Transition. Cycling and walking, in particular, need to be safer in order to increase take up. They reduce not only pollution and congestion but also improve health and well-being.

12.3.4. Results of the Horizon 2020 funding activities: pathways to impact

The figure below shows the outcomes for SC4 in the H2020 Theory of Change.

Coordination & Collaboration	Knowledge & Capacity	Market & Business	Technology & Innovation	Policy & Standards
• Stronger pan-European collaboration across disciplines, sectors, value chains and technology levels • Cross-border and cross-sector coordination and integration of R&I efforts	• Better understanding of local and regional specificities , user behaviour and perceptions • New European multimodal transport management systems • More service oriented transport System • Access to new knowledge	• More competitive and cooperative Industry • Access to new Markets • More sustainable manufacturing of innovative systems and equipment	• Comprehensive, intermodal and appropriate systemic solutions • New European Information and payment systems • New generation of innovative and environmentally friendly air, waterborne and land transport means • Efficient interfaces between long distance and urban mobility networks	• More informed transport policies • New transport standards

Figure 247 Expected Outcomes across all analysed calls.

The following sections will provide evidence for each of the pathways.

12.3.4.1. Coordination & Collaboration Pathway

Coordination and collaboration between stakeholders and across transport modes play a key role in increasing safety in mobility and transport. Understanding behaviour and decision-making in different countries and cultures is an important part of identifying solutions in a more integrated Europe. We first look at collaboration and coordination across geographies and cultures, secondly at collaboration to enhance the spread and use of knowledge and thirdly, collaborations and coordination up and down the supply chain.

Collaboration in R&I for Sustainable and Safer Transport contributes to addressing some of the challenges highlighted under Flagship 6:

"…..lack of harmonisation and coordination of relevant traffic rules and liability for automated vehicles needs to be addressed."*[28]*

Collaboration across geographies and cultures: Geographical collaboration played an important part in the portfolio of projects assessed here. For example, culture influences how individuals react to warning signals in a transport setting, be these sent by autonomous vehicles to shift control of the car back to the driver or by level crossings warning approaching road vehicles and trains of any failure which can lead to accidents, impacts significantly on safety. Testing new technologies in different local settings across Europe is an important contribution to increased safety (see, for example, the projects BRAVE and SaferLC, which both tested in a cultural context, but highlight the need for further testing).

In addition to collaboration within projects – i.e. international collaboration and partners from third countries – there is also evidence for collaborations across projects. Examples include:

- The final conference of the SAFESTRIP project included representatives from the SAFE-10-T project and the SAFERLC project.
- The contribution that the BRAVE project made to a follow-up project funded under H2020 in the 2018 – 2020 work programme, Trustonomy (Building Acceptance and Trust in Autonomous Mobility). Trustonomy makes direct use of the results of BRAVE, and the BRAVE coordinator is a member of the Trustonomy advisory board.[29]

These links between projects can ensure knowledge transfer as well as a continuation of research after the closure of a project. It is also noticeable if this collaboration across time is not feasible, as is the case in railway safety-related research, where this case study revealed gaps in the Horizon Europe Programme. Interviewees for this case study were concerned that knowledge that had been developed would be lost in the future.

Collaboration to enhance knowledge exchange: Safer transport is a fast-moving area of research, as autonomous vehicles demonstrate. Here spreading and broadening the knowledge base across Europe is one of the roles that collaboration and coordination play.

Linked to the broadening of the knowledge base is also the training and development of the next generation of scientists.

“International networks – that is really important for the careers of younger scientists.” Expert

Collaboration to enhance knowledge exchange has been the focus of the SaferAfrica project. This aimed at exchanging insights from learning in the European context, especially around the establishment of a safer system rather than just safer vehicles or safer vehicle users. This approach has been key to reducing fatalities and severe injuries in Europe: “*Greater knowledge of Safe Systems principles*.” is one of the impacts of the project.

The project Safer Africa further demonstrates how tried and tested knowledge can save lives across the globe. The project first assessed the available data on road safety, designed and implemented an Africa Road Safety Observatory and conducted an in-depth analysis of available training modules. Based on this analysis, the project set up twinning programmes on road safety with a “Train the Trainer” approach and collected information on good road safety practices across both continents in order to formulate and implement recommendations. The target audience was primarily decision-makers and funders. Figure 267 shows the links to decision-makers.

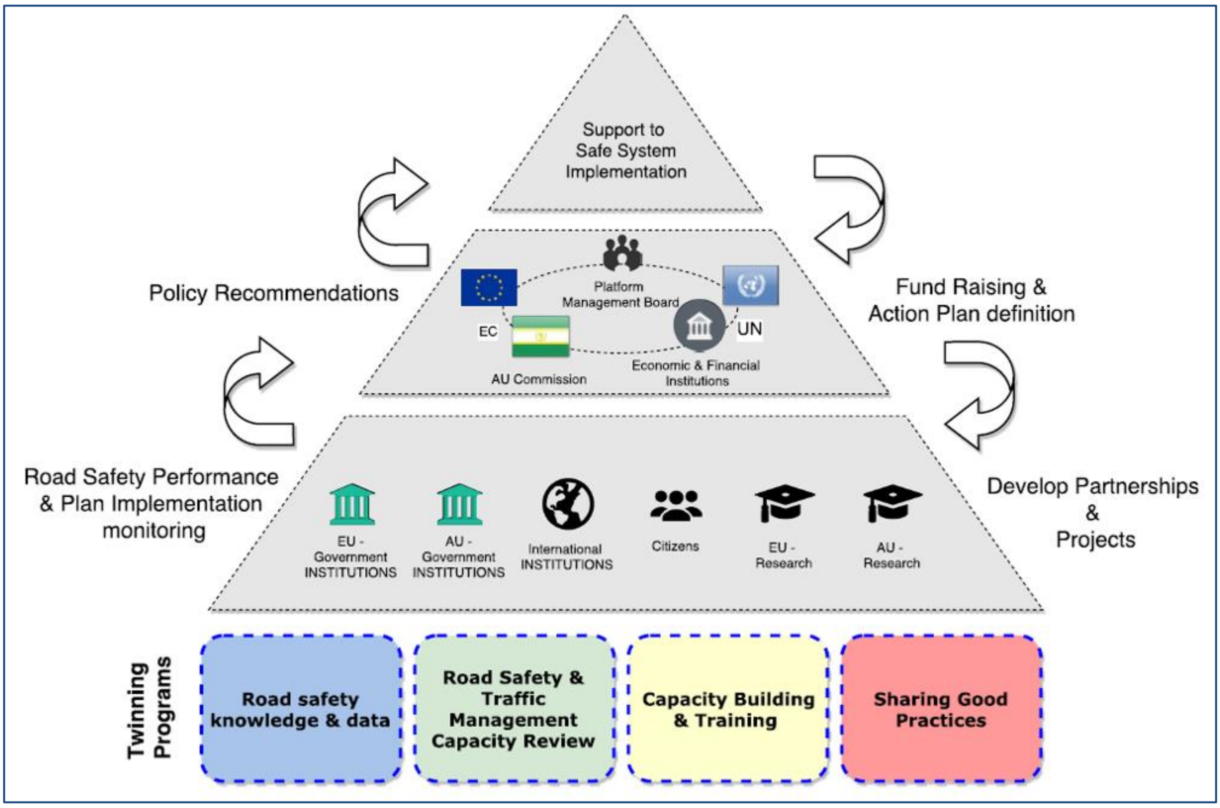


Figure 248 Safer Africa Concept.

Source: Periodic Reporting for period 2 - SaferAfrica (Innovating dialogue and problems appraisal for a safer Africa) – Reporting Period: 2018-04-01 to 2019-09-30

Learning across continents, including in collaborations with the US, India, members of the African Union and Australia, have contributed to achieving the objectives of the calls in H2020. This form of collaboration brings insights from different cultures, technologies and approaches to their use into the frame of R&I.

However, there have also been difficulties in organizing collaborations and keeping them alive, especially where no funding was provided by the EU. Some projects experienced insufficient contributions from Third Country Partners. In some projects, research ties were not sufficiently strong to incentivise partners and were not replaced by financial incentives.

Collaboration along the supply chain: Collaboration is also important along the supply chain within a sector. Several of the projects included in this case study bring together parts of the supply chain, e.g. developing the IT and software, integrating this into vehicles or infrastructure (e.g. BRAVE, INTERACT, SAFE STRIP), testing it in real-life settings to gain a good understanding of human behaviour and finally sharing this information with decision makers such as EU-NCAP. Projects working on the development of autonomous vehicles identified collaboration with the car manufacturing industry as important to ensure newly developed technologies and systems are integrated and can work in vehicles sold.

However, researchers also felt that in fast-moving areas, some of the partners withheld information in order to maintain their market position. The automotive industry was one of those named in this context. The industry is understood to be at the forefront of the development of autonomous vehicles. Those European companies that are seen as leading the market appear to be keen to protect their intellectual property rights and do not bring their most cutting-edge results to the table.

12.3.4.2. Knowledge & Capacity Building Pathway

The projects analysed in this case study produced actionable and practical knowledge. This feeds through into the Policies and Standards outcomes (section 12.3.4.3.5). They also identified a need for further research and a realization that some ambitions could not be fulfilled in the time first expected, especially in the area of autonomous vehicles.

A better understanding of local and regional specificities, user behaviour and perceptions: Seven of the nine projects take into account the regional or country-based differences across the EU. This means that new systems or applications are tested in different contexts. Examples include:

- TIMON: the project has been piloted satisfactorily in Helmond in the Netherlands and Ljubljana, Slovenia, where it has been a big success.
- SAFE-T-10: project results considered the safety of transport infrastructure assets in the Netherlands, the UK and Croatia. It identified differences in asset failure risks depending on the local context.
- SEDNA: safe and sustainable transport of goods and people in a hazardous and vulnerable environment of the Arctic region. International cooperation within the project will need to be matched by international implementation of research results to ensure these transport routes are used sustainably and safely.

However, further testing may still be necessary for other technologies:

- SaferLC: need for testing across different contexts (the alert app has only been tested with taxi drivers in Thessaloniki).
- BRAVE had not been able to test the autonomous system it developed quite as extensively due to COVID.

New European multimodal transport management systems: Safety depends in many cases on the interactions between different modes of transport. Rail and road are one more obvious example. On the road, cyclists, pedestrians, and others interact with cars and other more powerful vehicles. These interactions can put the safety of weaker and vulnerable users at risk.

Projects analysed for this case study, such as TrustVehicle and BRAVE, explored how these interactions can be addressed in a world where autonomous vehicles are added to the mix of existing road users. Being able to predict the decisions of pedestrians while reducing congestion and increasing efficiency within busy urban areas is a challenge that was explored in the projects included in this case study.

Infrastructure management, an important part of a safe transport system, was also addressed in the projects included here. Bridges, road surfaces and level crossings with smart technology allow communication with and between different transport modes (e.g. trains communicating with road vehicles). This acknowledges that transport modes interact with each other and need to be actively coordinated to increase safety.

More services-oriented transport system: Transport, including road transport, is increasingly seen as a service. For example, autonomous vehicles are allowing the driver to do other things in safety, enabling more productive use of time.

The box below provides an example of a project which has a strong services-oriented outlook, including improving the experience of vulnerable transport users.

Box 2. Example of a service-oriented project: TIMON.

TIMON will establish a cooperative ecosystem integrating traffic information, transport management, ubiquitous data and system self-management to provide the following services:

- Driver assistance services
- Services for vulnerable road users
- Multimodal dynamic commuter service
- Enhanced real-time traffic API (Application Programming Interface)
- TIMON collaborative ecosystem

Source: TIMON, Enhanced real-time services for optimized multimodal mobility relying on cooperative networks and open data, D8.6 Publishable Summary, 2016

Intelligent infrastructure also improves service levels. For example, the results of Safe-10-T increase the lifespan of infrastructure and avoid unnecessary maintenance, which reduces service interruption and environmental impacts.

Access to new knowledge: All projects included in this case study have provided access to new knowledge.

- The toolbox developed by SaferLC is still being updated and used. It is a tangible example of the access to and accessibility of new knowledge created. There is significant interest in the toolbox from EU countries as well as third countries where safety at level crossings is more of a problem than in Europe.
- SEDNA developed nature-inspired anti-icing solutions for vessels using the Arctic shipping route, which are available to mariners increasing safety and reducing environmental impacts.

Training in the tools developed by the projects is one important part of knowledge sharing and further knowledge development.

Scope for further research: Safety will always be a concern in the area of transport because of human interaction and reactions to new means of transport. Integrating behavioural science more into the technical R&I work is essential to making transport safe, especially as openness and willingness to shift between modes are becoming ever more important to enable the Green Transition.

12.3.4.3. Market & Business Pathway

European industry is at the forefront of sustainable and safe transport, as reflected in the safety standards across the continent. However, global competition requires continuous improvement and development to achieve the following:

- More competitive and cooperative industry,
- Access to new markets and
- More sustainable manufacturing of innovative systems and equipment.

More competitive and cooperative industry**:** Interviewees have described the technologies developed by the projects included in this case study as fast-moving. While expectations, for example, for autonomous driving, have at times been unrealistic, there are clearly opportunities which are already being used to increase safety in all forms of transport. The route to market will depend on the individual projects and the supply chain within relevant markets. It includes large motor vehicle manufacturers, IT and Software Developers, as well as infrastructure companies and public sector organisations that own and manage infrastructure.

Private, for-profit organisations play an important role in the projects assessed for this case study, even if not as large a role as for other areas of research under SC4. Their use and further development of the technology for the market will be important for this impact pathway.

Figure 5 shows the Business Model Development for SAFE STRIP, a project that focuses on infrastructure development but which requires software, sensor and vehicle development as well.

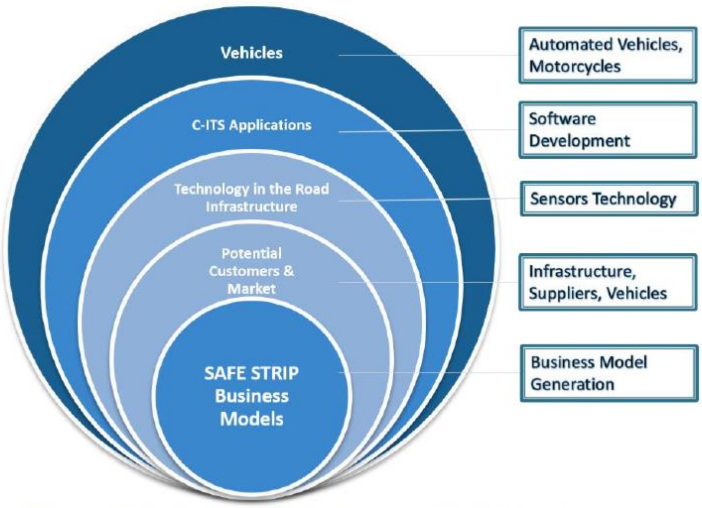


Figure 249 SAFE STRIP Business Model Development

Source: SAFE STRIP, SAFE and green Sensor Technologies for self-explaining and forgiving Road Interactive aPplications, D 8.3 Final Project Report

Access to New Markets: As demonstrated in SAFE STRIP, industrial partners play an important role in accessing new markets or designing more sustainable manufacturing of innovative systems and equipment. The total market for the integrated transport domain is estimated to be around US$ 34bn.[30] The route to market and final use of the research results requires cooperation along the supply chain of the whole transport system. Success stories identified by the case study consider the transport system as a system. An example is here the toolbox provided by SaferLC, which includes tools for road vehicle drivers, pedestrians, rail companies and infrastructure owners alike.

More sustainable manufacturing of innovative systems and equipment: Private companies, especially vehicle manufacturers, are seen as essential market participants to enable a more competitive and cooperative industry which allows EU companies to access new markets. All projects analysed for this case study highlighted the need for private sector companies to play a role in the improvement of safety.

Railway-oriented projects have a less clear route to market and business development. However, the interest expressed by the US in learning from experiences in Europe with improved safety demonstrates opportunities in this sector which in many cases is more dominated by the public sector. Similarly, international maritime research, as demonstrated in the project SEDNA has international companies and multilateral organisations as interested parties to drive the development and manufacture of innovative equipment.

In contrast to the identified need for private sector involvement and the obvious interest private sector companies have in the results of the projects included in this case study, several interviewees also expressed a sense of frustration with the large manufacturers. Especially the large car manufacturers with significant R&D budgets are perceived as not contributing their most up-to-date knowledge in the joint projects in order not to give access to commercially confidential information, even if this holds technology back. While there are clearly opportunities to benefit from the research, it is likely that more could have been achieved, for example in the area of autonomous vehicles, if more use of spill-over effects could have been made by including all cutting-edge knowledge. In these technology areas, interviewees spoke of a spreading out of existing knowledge and technology to a broader group of European scientists rather than spearheading new technologies.

While in some areas investigated by the projects, the US or India were named as potential markets for European technology, in others, it was acknowledged that third countries (esp US and Japan) were well ahead of European producers and EU firms had to focus on addressing European concerns and R&I needs.

One subsector where the private sector was not contributing as much and could develop further in order to increase safety and enable a Green Transition was named the bicycle manufacturers. Their R&D budgets are significantly smaller than in the car industry, leading to lower research activity. Safety regulations could be used in order to achieve the EU’s aspiration of a modal shift to less polluting modes of transport such as cycling.

12.3.4.4. Technology & Innovation Pathway

All projects included in this case study contribute to this pathway. Recognising intermodal linkages, the need to increase efficiency in the transport system, the use of environmentally friendly fuels and enabling users to choose the least environmentally harmful transport mode.

Within this complex technology and innovation system, safety is the overarching concern. The projects included in this case study focus on the reduction of the role of human decision-makers in transport in order to increase safety.

Comprehensive, intermodal and appropriate systemic solutions: The human-vehicle interaction at the node between different modes of transport is one of the causes of accidents. Projects included in this case study aim to address this:

- BRAVE, INTERACT and TRUSTVehicle aim to overcome the human errors which cause most accidents (see section 2.1) by combining the development of enhanced autonomous systems which also create and maintain trust within users with machine learning and communication tools.
- SAFER-LC successfully developed a toolbox in order to enhance safety at the intercept between railway, road and humans, making extensive use of behavioural sciences as well as technology development.

Despite these successes, some interviewees expressed doubt about the actual progress achieved compared to what has already been researched and developed in the industry.

New European information and payment systems: Within Europe, transport and mobility have to be understood as one system, not only at border crossings but also within countries, as users are increasingly travelling across the continent. This means that information systems need to be able to interact and be understood by all. Pooling and sharing information about successful steps to reduce accidents is therefore important.

Open data and information systems play an important role in enabling the cross-European use of more efficient and autonomous transport systems. Systems which enable machine learning in trains, as well as road vehicles, will need to be Europe-wide so as not to become an obstacle to the internal market and personal mobility.

Cooperative intelligent transport systems are one of the deliverables which are likely to be available to cities across Europe to collect information about traffic congestion and more. This domain can then assist public transport planning and emergency services and enable vulnerable road users, including visually impaired citizens and visitors, to plan ahead. Sustainability and Green Transition can also be supported as the systems developed allow a reduction in the environmental footprint of cities.[31]

More efficient traffic management: Several of the projects included in this case study investigate the introduction of autonomous vehicles into the daily traffic on European roads.

Some interviewees made clear that the interaction with individual road users, especially pedestrians, is more complex than envisaged. However, they were able to conduct real life – real vehicle tests moving closer to a new generation of transport means.

At a global scale, research conducted in the SEDNA project will enable shipping to take the shorter route to the North Pacific, increasing efficiency.

Encouraging and enabling transport mode changes by increasing rail safety and reducing infrastructure failure, in particular, where modes of transport interact (e.g. railway bridges across roads), will contribute to more efficient systems across Europe. This also includes advanced infrastructure to vehicle communication to enable early warning systems, which increase safety and reduce inefficiency at the same time.

12.3.4.5. Policy & Standards Pathway

Safety regulation is an important aspect of mobility. Any changes to vehicles, fuels, infrastructure, transport management and more will need to comply with existing regulations. In addition, there will be public perceptions of safety which influence individual choices and policymakers. Contributing to the public discourse and offering new, safe and sustainable modes of transport or changes to the transport system is, therefore, an important contribution by R&I.

As already noted, there is close alignment between the objectives and results achieved by the projects analysed here and the 2050 policy target (see Transport White Paper) of close to nil death in transport. Projects contribute by creating low-cost interventions and developments of new standards which can reduce risks of injury and death.

In addition, the projects included in this case study also align well with the SDGs 3.6 and 11.2. (see section 2.2.2) by providing low-cost, open-access tools as well as direct cooperation with the African Union as part of SaferAfrica (see Figure 4)

Low-Cost Interventions:

Box 3. Low-cost solutions: SaferLC.

SaferLC – low-cost solutions to reduce fatal accidents and severe injuries at the level crossing

SaferLC solutions include behavioural approaches based on

- Road colour,
- Narrowing the road before Level Crossings
- Introducing Speedbumps

These approaches are combined with alerts for drivers, intelligent Level Crossings that communicate with trains and vehicles and alert systems for drivers.

Four of the projects included in this case study have as part of their objectives to provide low-cost solutions to safety problems, reducing loss of life and injuries: TIMON, SaferAfrica, SaferLC and SafeStrip. Box 3 provides an example.

Development of new standards: Safety standards in all transport modes have to be developed and tested across borders. This is particularly the case in Europe, where the internal market uses all modes of transport, and goods cross several borders when moving from producer to end user. All participants need to be able to understand the standards set and adhere to them.

The calls and projects analysed for this case study use the participants' networks (see Figure 3) to test new systems, tools and R&I results in different settings. Robust testing is required for any new standard to be implemented and recommended to decision-makers. BRAVE, one of the projects assessed here, has been successful in working with and influencing EU-NCAP to use the project R&I results.

Safety of waterborne transport also faces safety issues in challenging environments such as the high seas. Here safety for the users has to be balanced with safety for the environment, whether in the choice of fuel for vessels or goods that can be transported. International stakeholders need to agree on regulations and standards.

12.4. Conclusion

EQ 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

The European policy objective of bringing the death toll for all transport modes close to zero is still a way off. The calls and projects analysed for this case study provide a better understanding of human–machine interaction, contributed significantly to gaining an understanding of the role of behaviour in this interaction and have aimed at a holistic approach to including infrastructure, vehicles and people into potential solutions. This is clearly a move in the right direction.

Human-vehicle interaction plays an important role in the development of autonomous vehicles. Here the research funded by the H2020 programme made clear that it is not just an issue of safer vehicles but also how drivers and pedestrians interact with the vehicle or how drivers judge risks, for example, in the case of road–rail interaction at crossings.

Safe infrastructure plays an important role in safer transport. Using technology to make infrastructure active and reporting weaknesses for repair combines the need for safety with efficient use of resources which is part of the Green Transition.

The research has further shown that there are nature-based solutions which can increase safety in hazardous conditions enabling a reduction of the environmental footprint of long-distance transport.

Further work will need to be done to predict human behaviour, especially at those points where people interact with machines or infrastructure. Taking into account cultural differences across Europe and learning from third countries as well as applying learning from Europe globally, will be important contributors to advances across the globe in increased safety.

EQ 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact?

This case study identified two drivers of success for research in this area: one concerning the fields of research and another the research teams themselves. Within the sets of drivers of success, 6 specific factors can be identified:

- **Interdisciplinary research:** Understanding the links between behaviour and technology was a major driver of success for the projects involved in this study, i.e. understanding safety from the human factor perspective as well as the technology and bringing these together.
- **Bringing together users and providers of new technology for testing**: Testing in different cultural and socio-economic contexts matches the fact that there is a European Transport system consisting of many users with different backgrounds.
- **Nature-based and simple solutions:** Toolboxes to be used across many different countries need to be clear and simple without being simplistic. Nature-based solutions, well-aligned with the objectives of the Green Transition, also help in hazardous situations in maritime navigation.

- **The innovation process is not uniform in this area:** The case study revealed that the innovation process, for example, in the area of autonomous driving, is one of a (small) step-by-step development, with real-world testing in between, which does not always lend itself to large project teams. Matching the number of project participants to the innovation process and enabling smaller teams may be more beneficial for some developments.
- **Decision makers sit at many different decision-making levels across the EU Member States**: Decisions which can lead to the take-up or neglect of R&I results range from local Government to national Government, public sector organisations and private entities. Dissemination of relevant results is, therefore, complex.
- **Highly motivated team and coordinator**: Having a good coordinator who allows people to work the way they want and needs but ensures results are fed in when needed is key to success.

E.Q. 4.3: ***To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts?***

Several of the projects included in this case study had events planned for 2020 or 2021. These had to be moved online due to the COVID pandemic. These online conferences have proven more useful in disseminating the results of R&I than first anticipated, opening up dissemination to more stakeholders, especially in third countries.

Twitter and other social media platforms have also been useful dissemination tools.

Some projects identified the need for a list of "*real stakeholders*" from the Commission and national and regional governments that can make actual use of the results. In the field of transport safety, infrastructure plays an important role in safety. It is managed by national or local agencies, with international agencies setting standards. Public organisations interact with private companies. The Commission could support the dissemination more across these different organisations by using its networks more.

Close cooperation with other projects also played an important role for projects in this case study. Using experts from sister projects or follow-up projects can ensure that research results are followed through into the future.

EQ 4.5. To what extent has international cooperation and, more specifically, association of third countries to the EU Framework Programme made a difference in achieving the environment related objectives of the Framework Programme?

Knowledge exchange and the testing of results in different cultural contexts are key to ensuring that the European Transport system works as one. Extending this to third countries has widened the viewpoint of several of the projects.

Cooperation with third-country partners was an important part of the work. However, it has also proven difficult. There is evidence that third-country partners being not as well funded and dedicated to the specific tasks under the EU projects, have not been able to commit as much resource as would have been necessary and beneficial. However, there has been evidence to the contrary, especially regarding the exchange of scientists in the early stages of their scientific careers.

EQ 5.1. What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?

Partnerships make a difference. National research would not have the same impact because of too narrow a focus when many of the R&I questions are international.

Transport systems across the EU have become more integrated, enabling the trade of goods as well as international travel. EU R&I in the area of safer transport enables this further integration. R&I across the EU compared to national R&I adds this additional perspective of integrated transport, similarly for the global transport of goods across the Arctic, where international approaches are essential to moving towards a safe green transition.

The calls and in particular the projects analysed have enabled identifying solutions that work in different social and cultural contexts. Including third countries in this process not only enables best practices being used elsewhere but also enables the European industry to match demands and requirements from elsewhere.

12.5. Annexes Facts on Safety in Transport

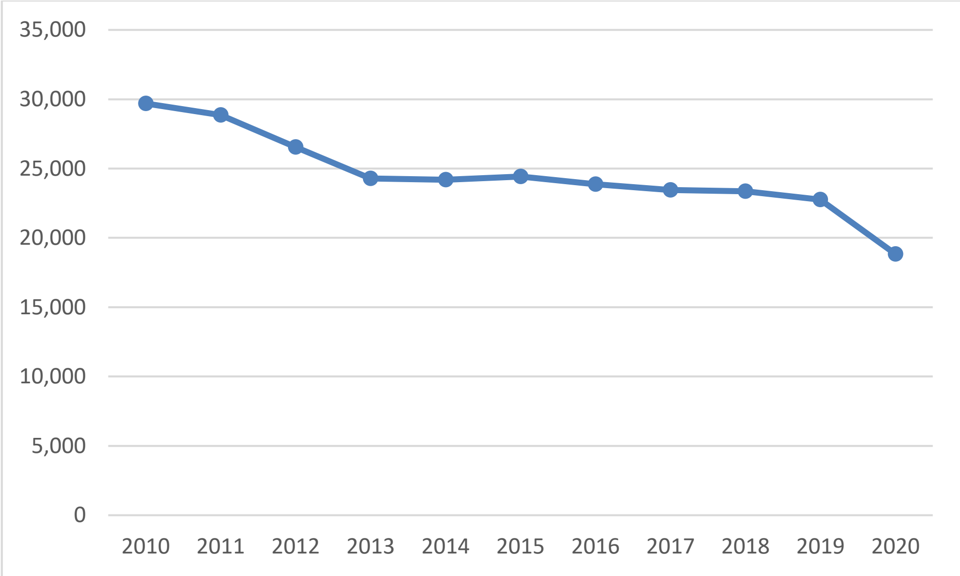
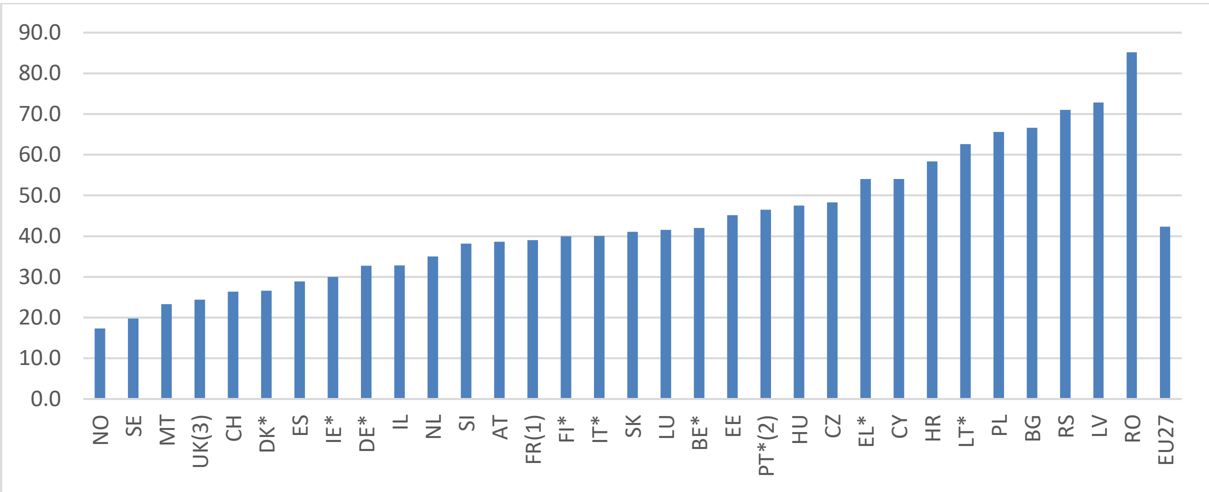


Figure 250 Road deaths in EU 27, 2010 to 2020.

Source: European Safety Council, Road deaths in the European Union – latest data | ETSC



*National provisional estimates used for 2020, as the final figures for 2020 were not yet available this report went to print.

(1)FR - continental population data.

(2)PT - continental population estimate. 2020 road death and continental population data provided by the National Road Safety Authority (ANSR).

(3)UK - 2020 estimate is based on GB provisional total for the year ending June 2020 (1580 deaths) and the provisional data for Northern Ireland for the calendar year 2020 (56 deaths).

Figure 251 Deaths per mln inhabitants, by country, 2021.

Source: European Safety Council, Road deaths in the European Union – latest data | ETSC

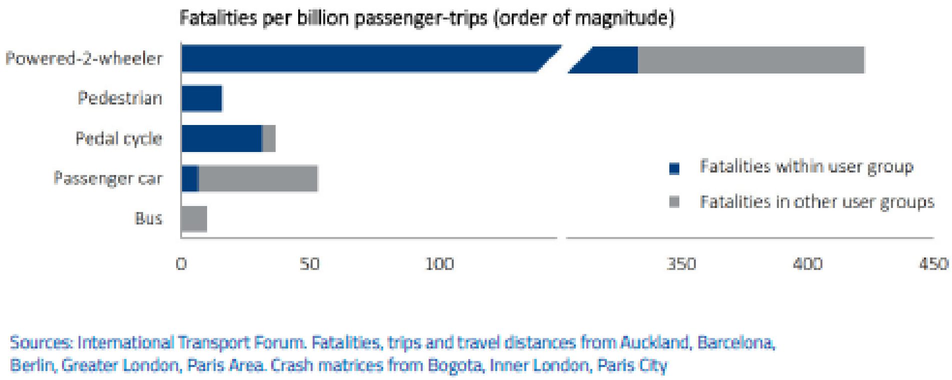


Figure 252 Fatalities per billion passenger trips by transport mode.

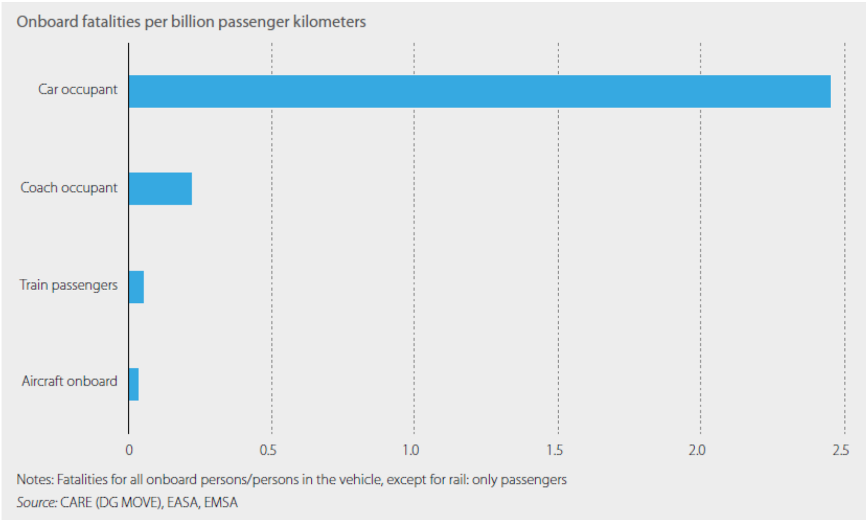


Figure 253 Passenger and driver fatality rates for different transport modes (EU-28, 2014 – 2018).

12.5.1. Key metadata of the case study no. 12 Future Transport: Sustainable and Safe for All

Table 105. Key metadata of case study no. 12 Future Transport: Sustainable and Safe for All.

Case no. 12	Future Transport: Sustainable and Safe for All
Evaluation Question addressed*	EQ 4.2.; 4.3; 4.4.; 4.5.; 5.1.
Area	Sustainable Transport
Programme parts	WP 2014/2015 () WP 2016/2017
Scope	4 Horizon 2020 calls Time horizon covered: 2014 – 2020. Number and type of instruments analyzed: 8 RIAs, 1 CSAs 3 Partnerships: one JU, 1 PPP and 1 EIT KIC Number of projects analysed: 9
Key data sources	H2020 Work Programs & relevant call text Project data from CORDIS & CORDA 6 interviews (with 8 people) (2 Experts, 2 Policy Officer, 4 Project Beneficiaries) Strategic Policy Documents (Transport White Paper, Mobility Strategy)
Links with partnerships	SHIFT2RAIL CCAM EIT Urban Mobility
Relevant policies	EU Transport White Paper, 2011 Mobility Strategy, 2020 European Council Conclusion, Putting Rail at the Forefront of

	Smart and Sustainable Mobility, June 2021 European Maritime Safety Agency, EMSA, 5 -YEAR STRATEGY, 2020 - 2024 United Nations Road Transport Safety Fund Sustainable Development Goals 3 and 11

Table 106. Project information.

Project Acronym	Project Call ID	Action Type	EC Net Contribution	Project Start	Project End
SaferAfrica	H2020-MG-2016-SingleStage-RTD-MOVE	CSA	2844275	1 Oct 2016	30 Sept 2019
TIMON	H2020-MG-2014_TwoStages	RIA	5605213	1 June 2015	30 Nov 2018
BRAVE	H2020-ART-2016-Two-Stages	RIA	2990538.75	1 June 2017	28 Feb 2021
SAFER-LC	H2020-MG-2016-Two-Stages	RIA	4888927	1 May 2017	30 April 2020
SAFE STRIP	H2020-MG-2016-Two-Stages	RIA	4595813.75	1 May 2017	31 Aug 2020
SAFE-10-T	H2020-MG-2016-Two-Stages	RIA	2997000	1 May 2017	30 Apr 2020
TrustVehicle	H2020-ART-2016-Two-Stages	RIA	4998903.75	1 June 2017	31 Oct. 2020
interACT	H2020-ART-2016-Two-Stages	RIA	5527581.25	1 May 2017	09 Sept 2020
SEDNA	H2020-MG-2016-Two-Stages	RIA	6498752.5	1 June 2017	30 Nov 2020

12.5.2. Tables of Horizon 2020 calls analysed

Table 107. H2020 calls analysed.

WP 2014/2015 (Smart, Green and integrated Transport)	• MG.3.6-2015. Safe and connected automation in road transport
WP 2016/2017 (Part17 Cross-Cutting Activities)	• ART 04 2016: Safety and end-user acceptance aspects of road automation in the transition period • MG 3.3 2016 : Safer waterborne transport and maritime operations • MG 3.4 2016 Transport infrastructure innovation to increase the transport system safety at modal and intermodal level (including nodes and interchanges)

12.5.2.1. International and European strategies related to sustainable and safe transport for all

At the international level, the United Nations Road Safety Fund The UN Road Safety Fund (UNRSF or the Fund) was established in 2018 as a UN multi-partner trust fund pursuant to the General Assembly resolution 70/260 and with the support of the UN Secretary-General. The secretariat of the Fund is hosted in Geneva, Switzerland by the United Nations Economic Commission for Europe (UNECE). Its administrative agent is the United Nations Multi-Partner Trust Fund Office in New York.

Its mission is to finance and leverage further funding for high-impact projects based on established and internationally recognized best practices that increase road safety, minimize and eventually eliminate road crash trauma for all road users.

At the European level, the European Transport White Paper, 2011, Roadmap To A Single European Transport Area — Towards A Competitive And Resource-Efficient Transport System , 2011 set a target of moving to close to zero fatalities by 2050. This is still the guiding target for road safety.

12.6. References

[1] See for example SHIFT2RAIL

[2] Horizon 2020, Work programme 2014 – 15, p 30

[3] Source: European Union Agency for Railways, Report on Railway Safety and Interoperability in the EU, 2020

[4] Thomas, Pete ; Morris, Andrew ; Talbot, Rachel; Fagerlind, Helen, Identifying the causes of road crashes in Europe, Annals of advances in automotive medicine / Annual Scientific Conference ... Association for the Advancement of Automotive Medicine. Association for the Advancement of Automotive Medicine. 2013

[5] Source: TIMON, Connecting road users and infrastructure in the cloud for increased safety on the ground, Results in Brief, 2018

[6] Innovating dialogue and problems appraisal for a safer Africa, Periodic Reporting for period 2 - SaferAfrica (Innovating dialogue and problems appraisal for a safer Africa), Reporting period Apr 2018 – Sept 2019

[7] See Periodic Reporting for period 2 - SAFER-LC (SAFER Level Crossing by integrating and optimizing road-rail infrastructure management and design), reporting period, Nov 2018 – April 20.

[8] EU Priorities and actions, Transport : https://european-union.europa.eu/priorities-and-actions/actions-topic/transport_en

[9] European Environment Agency, INDICATOR ASSESSMENT, Greenhouse gas emissions from transport in Europe, 2018

[10] For a summary of these policies, please see Annex A.3

[11] Roadmap To A Single European Transport Area — Towards A Competitive And Resource-Efficient Transport System, Transport White Paper, 2011

[12] General Secretariat of the Council, No. prev. doc.: ST 8642/21, Council conclusions on "Putting Rail at the Forefront of Smart and Sustainable Mobility", June 2021

[13] Sustainable and Smart Mobility Strategy, Putting European transport on track for the future, 2020

[14] European Commission, Efficient and Green Mobility, IMPROVING ROAD SAFETY AND DRIVER COMFORT through digitalisation, December 2021

[15] Sustainable and Smart Mobility Strategy, Putting European transport on track for the future, 2020

[16] Where safe, economically advantages modal choices are available, people ,ake them Example the Madrid to Barcelona train services versus plan, end note 26 of 2020 mobility strategy.

[17] European Maritime Safety Agency, EMSA, 5 -YEAR STRATEGY, 2020 - 2024

[18] SDG Knowledge Hub

[19] Source: SDG Knowledge Hub

[20] The Road Safety Fund, Invest in the Future Invest in safe mobility, UN 2018, https://unece.org/publications/oes/welcome?f%5B0%5D=program%3A453&f%5B1%5D=work_area%3A1111

[21] Using definition of RIA as provided in the COMMISSION STAFF WORKING DOCUMENT IN-DEPTH INTERIM EVALUATION of HORIZON 2020.

[22] https://rail-research.europa.eu/about-shift2rail/mission-and-objectives/

[23] Note that a more detail evaluation of SHIFT2RAIL is included in this evaluation [add link to section].

[24]https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/s2r-cfm-cca-03-2015;callCode=null;freeTextSearchKeyword=H2020-S2RJU-2015;matchWholeText=true;typeCodes=1;statusCodes=31094501,31094502,31094503;programmePeriod=null;programCcm2Id=null;programDivisionCode=null;focusAreaCode=null;destination=null;mission=null;geographicalZonesCode=null;programmeDivisionProspect=null;startDateLte=null;startDateGte=null;crossCuttingPriorityCode=null;cpvCode=null;performanceOfDelivery=null;sortQuery=sortStatus;orderBy=asc;onlyTenders=false;topicListKey=topicSearchTablePageState

[25] https://www.ccam.eu/#

[26] https://eit.europa.eu/our-communities/eit-urban-mobility

[27] https://eit.europa.eu/sites/default/files/eitum-urbanmobilitynext4.pdf

[28] Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions Sustainable and Smart Mobility Strategy – putting European transport on track for the future COM/2020/789 final, p 16, Flagship 6

[29] Trustonomy project beneficiary – expert to this case study

[30] SAFE STRIP, SAFE and green Sensor Technologies for self-explaining and forgiving Road Interactive aPplications, Grant Agreement Number: 723211, D8.3 Final Project Report, p 197

[31] SafeStrip, Final report.

13. Case study 13: Adaptation to climate action

13.1. Summary

The case study focuses on Horizon 2020 funding in the area of Climate Change Adaptation (CCA). This topic has increased in relevance over the course of the H2020 Framework Programme and assumed a prominent role in Horizon Europe. For the analysis of this case study, we conducted 6 interviews with key stakeholders and analysed roughly 500 projects under 84 calls, predominantly in Societal Challenge Area 5 and in other Societal Challenge Areas (2 to 4), all with high relevance to this case study.

The case study shows that the work programs have established a portfolio of interventions in CCA that provided an important foundation for progress towards EU policy priorities and objectives related to the Green Transition. The case study shows that the FP contributed to a) improved knowledge required to tackle climate challenges and contribute to achieving a green transition and b) creating enabling conditions for the realisation of a green transition across a wider range of countries across Europe and the globe, which include *solutions*. We identified six main enabling factors for the effectiveness of the portfolio, 1) focus on a systemic approach, 2) creating services that are relevant for a multitude of actors, 3) using showcases or demonstrators to make adaptation solutions known, 4) fostering the collaboration with non-academic actors through participatory and co-creation approaches, 5) fostering an international community in CCA research.

With the evolution of H2020, CCA has gained increased relevance and effectively helped lay the ground for the upscaling of efforts in the EU Mission on Adaptation to Climate Change.

13.2. Introduction and overview

13.2.1. Objectives of the case study

This case study identifies and analyses relevant actions related to what is largely regarded as Climate Change Adaptation[145] in Horizon 2020. It provides an assessment of the implementation of the

[145] The definition and implementation of 'climate change' within SC5 can be thought of as being part of a 'higher' climate action concept (i.e. with GHG emission-based targets for mitigation and adaptation or resilience actions at both MS, EU and international/UNFCCC levels). Furthermore and while CCA ("adaptation") and its R&I-based need and prioritisation can be considered through a specific perspective (i.e. within a knowledge-based / eco-system services framing), it is considered here

Framework Programme and shows how the results and outcomes of the funded projects contribute to the overarching goals of the Horizon 2020 programme conception and addresses the question of whether Horizon 2020 provided a solid basis for increasing climate change resilience within the EU and, overall, for the Green Transition. Against this background, the main objective of this case study is to analyse to which extent Horizon 2020 actions in SC5[146] enabled an effective approach that can be further scaled up in Horizon Europe.

The reason for the selection of this topic as a case study is that it (a) is an umbrella of sorts for many different and critical sub-areas of climate change, (b) has stood at the centre of attention of European R&I policy, (c) is a focus area within the Green Transition, and (d) also one of the five EU Missions[147] subsequently established under Horizon Europe. As such, its development over the lifespan of the 8th FP is of interest, in particular its evolution leading into Horizon Europe.

13.2.2. Scope of the case study

The case study focuses on Horizon 2020 funding in SC5 as a whole – across all three Work Programmes (2014/15, 2016/17, 2018/20) since the entirety of funded projects contributes to Climate Change Adaptation (CCA). In addition, selected projects from other Challenges (SC2/SC3/SC4) were analysed as well. The H2020 project portfolio used for this case study comprises roughly 500 projects under 84 calls with high relevance to the topics of the case study[148].

13.2.3. Methodology for the case study

The analysis comprised 84 Horizon 2020 calls. The time horizon covered with the analysis is 2014-2020. The number and types of instruments analysed are 234 Research and Innovation Actions (RIAs), 99 Collaboration Coordination and Support Actions (CSAs), and 155 Innovation Actions (IAs).

The analytical approach comprised a qualitative as well as quantitative part. While the former focused on reviewing the relevant work programmes, calls, and strategic documents related to Climate Adaptation, the latter set out to produce statistics on projects funded under the identified calls. The data on the identified projects come from Cordis/Corda.

In addition to the project data analysis, we performed 6 interviews with relevant stakeholders. The interviews comprised representatives of thematic experts involved in the European strategic process. Please see Appendix A for the overview of the interviewees. The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus.

To synthesise the results of these analyses, we triangulated the findings in relation to the evaluation questions and impact pathways.

13.3. Synthesis of evidence / Findings

13.3.1. Strategic policy priorities related to Climate Change Adaptation (CCA)

The early stages of the 8th FP had strongly been influenced by the Europe 2020 strategy – with its three mutually reinforcing priorities: smart, sustainable, and inclusive growth – and the 20-20-20 targets (20 % GHG emission reduction, 20 % increase in energy efficiency, and a share of 20 % renewables in the total energy consumption in the EU). What is now understood as CCA relates to climate action and sustainable development that had been established in Horizon 2020 as a cross-cutting programme priority and mainstreamed in Horizon 2020. At least 60 % of the overall Horizon

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through this case study that adaptation is considerably broader and holistic in scope (and within SC5). It includes a broad range of transdisciplinarity projects and focuses (e.g. also across governance, research, collaboration, etc.). In addition to this, *adaptation* is found to also be present as a topic in other SCs, such as SC2. The evidence also suggests the importance and relevance of adaptation within SC5 (and across other SCs) and as a key R&I component for enabling or implementing a broader green transition process

[146] Societal Challenge 5: Climate action, environment, resource efficiency and raw materials

[147] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe_en

[148] This case study partially corresponds with the institutional partnership case study EIT Climate-KIC.

2020 budget was expected to be related to sustainable development, with climate-related expenditure forming 35 % of the budget (including mutually compatible measures improving resource efficiency).

Regulation (EU) No 1290/2013 laid down the rules for participation and dissemination in Horizon 2020 – the Framework Programme for R&I (2014-2020). For sustainable development and climate change, the Horizon 2020 Regulation states: Horizon 2020 will encourage and support activities towards exploiting Europe's leadership in the race to develop new processes and technologies promoting sustainable development, in a broad sense, and combating climate change. Such a horizontal approach, fully integrated into all Horizon 2020 priorities, will help the Union to prosper in a low-carbon, resource-constrained world while building a resource-efficient, sustainable and competitive economy.

The topic is approached in Horizon 2020 through a series of actions and collaborative opportunities in Societal Challenge 5, "Climate action, environment, resource efficiency and raw materials". The Horizon 2020 Regulation (Art. 5, §2.) defined the objective for SC5 as being to (a) achieve a resource- and water-efficient and climate change-resilient economy and society, (b) the protection and sustainable management of natural resources and ecosystems, and (c) a sustainable supply and use of raw materials, to meet the needs of a growing global population within the sustainable limits of the planet's natural resources and ecosystems. It was further expected that the activities contribute to increasing European competitiveness and raw materials security and to improving well-being whilst assuring environmental integrity, resilience and sustainability with the aim of keeping average global warming below 2 °C and enabling ecosystems and society to adapt to climate change and other environmental changes.

A range of R&I-based activities is defined under SC5, which include: climate action; cultural heritage; earth observations; nature-based solutions; and systemic eco-innovation. It has broadly aimed through its implementation to enhance the transition to a more climate change resilient, resource efficient and competitive Europe while contributing to the UN Sustainable Development Goals (SDGs) and to the Paris Agreement.

As is true for Horizon 2020 in general and in particular with regard to climate change, a shift from the 7th to the 8th FP to a more challenge- and solution-based approach was made, especially with regard to mobilising societal actors and the private sector.

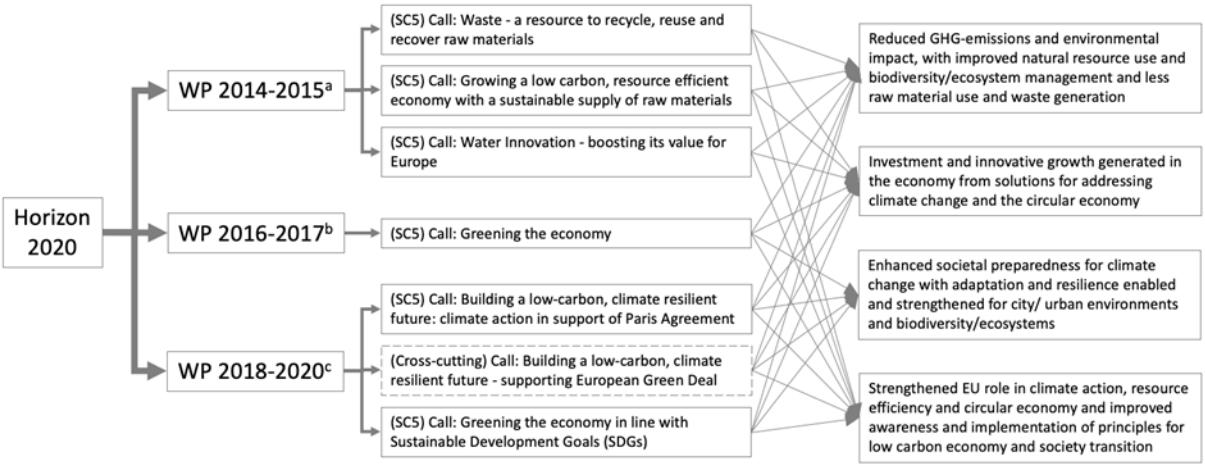
13.3.2. Horizon 2020 programming related to CCA (Climate Change Adaptation)

13.3.2.1. Horizon 2020 Work Programmes related to CCA

The first two Horizon 2020 work programmes for SC 5 (during 2014-2017) contributed towards the cross-cutting priorities of climate action and sustainable development and where, for example, as part of the implementation of the first SC 5 work programme (2014-2015), waste as a resource and water innovation were both seen as key priority areas for focus due to the opportunities for business and job creation as well as the need to address resource efficiency. During Horizon 2020’s implementation over 2014-2020, the climate change and sustainable development priorities within the objectives of SC 5 are considered to have evolved progressively, focusing on more systemic approaches. Two key areas have been highlighted to achieve those objectives. Firstly, climate change mitigation and adaptation and a focus on innovation and investment in climate research and green technologies. And secondly, the decoupling of economic growth and social development from resource exploitation and waste and focus on supporting a transition towards a circular economy.

With sustainable development forming a central component of SC 5 alongside climate action, the Horizon 2020 work programmes clearly contribute to a number of the SDGs, which include: SDG 6 (Clean Water), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action); SDG 14 (Life Below Water); SDG 15 (Life on Land).

The figure below shows how Horizon 2020’s work programmes have progressed through their respective calls for SC 5 during 2014-2020 and in relation to the focal / priority areas of each work programme. An indication is also provided where SC 5 has made a contribution to other societal challenges and their calls within Horizon 2020. NOTE the cross-cutting Green Deal call is also included in this figure as part of the Work Programme 2018-2020.



[a] **WP 2014-2015** includes SC5 contribution to: (SC7) Call - Disaster-resilience: safeguarding and securing society, including adapting to climate change; (SC2) Call - Blue growth: unlocking the potential of the oceans; (SC3) Call - Energy-efficiency.
[b] **WP 2016-2017** includes SC5 contribution to: (cross-cutting) Call - Industry 2020 in the Circular Economy; Smart and Sustainable Cities; (SC2) Call - Blue growth – demonstrating an ocean of opportunities, Call - Sustainable Food Security – Resilient and resource-efficient value chains; (SC3) Call - Competitive low-carbon energy.
[c] **WP 2018-2020** includes SC5 contribution to: (Cross-cutting) Call - Competitive, Low Carbon and Circular Industries.

Figure 254: Horizon 2020 SC 5 Calls and their WP focus/ priority areas (Technopolis 2022).

The 2015 Paris Agreement and its long-term goals to limit dangerous increases in temperature were integrated into the programming of Horizon 2020's final and third work programme (2018-2020), which was amended by the European Green Deal by ways of two dedicated calls:

- Building low-carbon, climate resilient future - climate action in support of Paris Agreement which focuses on:
  - A direct contribution to the Commission's European Green Deal Communication, contributing directly to the EU's Recovery Plan for Europe.
  - Operationalisation of Paris Agreement goals through high-quality policy-relevant evidence from the scientific community.
  - Acceleration of transformation towards carbon neutrality through co-design, co-development and co-deployment of technologies and services by researchers, entrepreneurs and citizens.
  - Enhanced climate resilience in Europe and beyond, in sectors such as health, infrastructure, water, agriculture and forestry, as well as in cities.
  - Long-term mitigation and adaptation policy planning, deployment of technology to reduce emissions and enhanced climate change resilience in developing countries.
- Greening the economy in line with the Sustainable Development Goals (SDGs)
  - Measurable improvement in resource use efficiency and effectiveness (primary and secondary), including energy.
  - Measurable reduction in waste generation, environmental pollution and greenhouse gas emissions, transforming recyclable waste into a flourishing market of secondary raw materials.
- Creation of competitive advantage for existing businesses.
  - Creation of new business opportunities, including disruptive innovation.
  - Enhancement of security of raw materials supply

Overall, the Work Programmes are coherent with other global or EU priorities, national strategies, directives, or roadmaps. The introduction of the SDGs made visible which goals the calls contribute to149.

13.3.3. Project portfolio characteristics

13.3.3.1. Horizon 2020 project portfolio

The portfolio of projects for this case study includes roughly 500 projects which are comprised of all – but the most recently – funded projects in SC5, as well as selected projects from other Societal Challenges (SC2-SC4) that were of high relevance for CCA.

The next sections break the portfolio up into various categories, i.e. into participation by stakeholder type, by type of instruments, and by country.

13.3.3.2. Participation by stakeholder types in H2020 projects

The sum of EC's net contribution is over EUR 3 bn, of which 31 % was allocated to research organisations (REC), 27 % to for-profit entities (PRC), 27 % to higher and secondary educations establishments (HES), 8 % to public bodies (PUB), and 7 % to other organisations (OTH); see table below.

Table 108. Types of organisations in H2020 projects related to CCA.

Type of organisation	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1000)	EC contribution Share (%)	EC Contr. per part. (EUR 1000)
HES	432	2203	23%	827 053	27%	375,4
OTH	325	1013	11%	214 512	7%	211,8
PRC	438	2959	31%	836 009	27%	282,5
PUB	269	891	9%	238 794	8%	268,0
REC	467	2439	26%	951 775	31%	390,2
Total (All types)	**490**	**9499**	**100%**	**3 068 142**	**100%**	**323,0**

HES: Higher or Secondary Education Establishments; PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments); REC: Research Organisations; PRC: Private.

Source: Science-Metrix, 2022, based on project data from eCorda.

A combined share of 58 % of funding went to REC and HES organisations, which was to be expected. The next biggest share went to PRC (27 %), showing that the private sector does play a perceivable role in the funded projects. Both PUB and OTH participated to a similar extent (8 % and 7 %, respectively).

Compared with the values aggregated over all Green Transition areas considered in the overall evaluation study (SC2 to SC5), the portfolio of CCA projects has a higher share of funding for REC (31 % vs 24 % overall). The same is true for HES (27 % vs 19 % overall) and, to a smaller extent, also for OTH (7 % vs 6 % overall) and PUB (8 % vs 5 % overall). There is a noticeable difference between funding for PRC, though 27 % vs 43 % overall, which may be attributed to the kind of research conducted in the portfolio of funded projects, as well as the predominant type of action/instrument (see next section).

13.3.3.3. Participation by type of instruments and type of stakeholder organisation in CCA- related H2020 projects

The share of funding allocated to the different types of action/instrument is as follows: 46.3 % to RIA (Research and Innovation Actions), 38.5 % to IA (Innovation Actions), and 15.1 % to CSA (Coordination and Support Actions), which is very much in line with the allocation found in the Green Transition areas overall (SC2-SC5).

[149] mainly to SDG 13 (Climate Action), SDG 6 (Clean Water), SDG 12 (Responsible Consumption and Production), SDG 14 (Life Below Water), and SDG 15 (Life on Land)

The share of each type of organisation participating in the funded projects heavily depends on the type of actions/instruments (see Figure 39). For instance – and as expected –the share of PRC is higher in IA than in RIA (44 % vs 26 %) and much higher in IA than in CSA (44 % vs 16 %). Conversely, the roles of REC and HES are smaller in IA in terms of the share of participating organisations (18 % and 17 % in IA vs 30 % each in RIA). The share of HES in CSA is fairly low compared to REC (18 % vs 32 %), while the share of REC remains roughly the same as in RIA (~ 30 %).

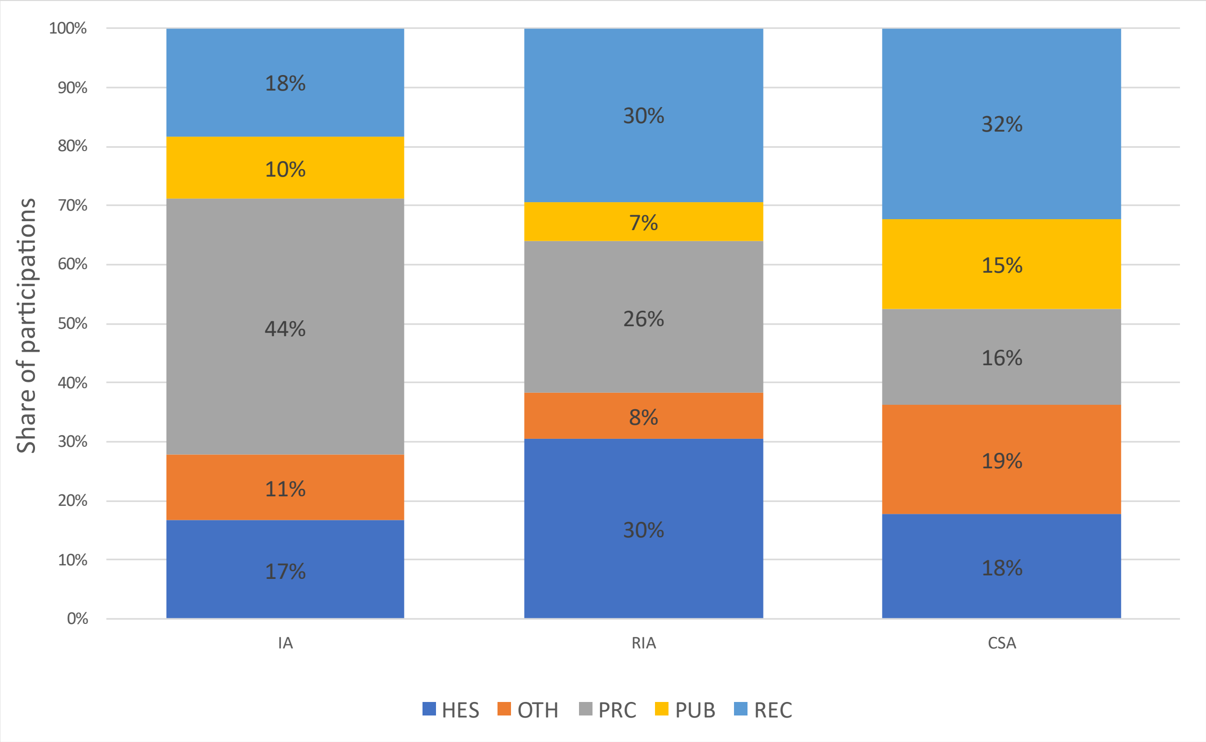


Figure 255 Share (%) of participations by type of stakeholder organisation and type of actions/instruments. IA = Innovation Action; RIA = Research and Innovation Action; CSA = Coordination and Support Action. HES = Higher or Secondary Education Establishments; PU = Public Organisations REC = Research Organisations PRC = Private Companies.

Source: Science Metrix, 2022, based on eCorda data

13.3.3.4. Participation by countries in CCA-related H2020 projects

The eCorda statistics show (see Table 73) that Associated Countries (excluding the UK) participated in 285 out of 490 projects (7.6 % share of the total number of project participations), Third Countries in 174 out of 490 projects (6 % share of participations).

However, in terms of funding, the latter group received only 2.2 % of the total funding, which shows that organisations from those countries predominantly play a minor role in funded projects.

There is a large gap in terms of project participation between the EU-14 and the EU-13 (69.8 % vs 8.7 % share of the total number of project participations), which is present in all Green Transition areas (SC2-SC5). The gap in terms of EC contribution/funding is even wider (74.9 % EU-14 vs 5.6 % EU-13), which may partly be explained by the fact that the median income in EU-13 is significantly lower than in EU-14; whether other factors contribute to this gap was not within the scope of this study. That said, the analysis of further participation characteristics may shed some light on the matter (see analysis of country participation below).

Table 109. Groups of countries' (of funded organisations) participation in projects of the case study CCA.

Group of country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Number of countries
H2020-EU27	485	7 459	78,5%	2 470 792	80,5%	331,2	27
EU-14	*482*	*6 634*	*69,8%*	*2 297 837*	*74,9%*	*346,4*	*14*
EU-13	*281*	*825*	*8,7%*	*172 955*	*5,6%*	*209,6*	*13*
H2020-associated (exclude UK)	285	722	7,6%	247 029	8,1%	342,1	16
United Kingdom	305	746	7,9%	282 972	9,2%	379,3	1
Third Countries	174	572	6,0%	67 349	2,2%	117,7	62
All-countries	**490**	**9 499**	**100,0%**	**3 068 142**	**100,0%**	**323,0**	**106**

Source: Science Metrix, 2022, based on eCorda data

The list of the 15 most active countries, in terms of the number of CCA-related Horizon 2020 projects they are involved in, is headed by Germany (366 projects), Spain (335) and Italy (310). These countries have also received the highest shares of EC funding (see table below).

This list confirms the low participation rate of EU-13 shown above. In fact, it does not even contain a single country from this group of Member States. This issue is not new and has long been a subject of concern whether this kind of exclusivity might have severe negative consequences – within CCA, those may affect the much-needed mobilisation of actors or critical increase of CCA efforts across Europe. The EU-13 lagging behind in terms of scientific excellence is one thing; a whole group of EU Member States lagging behind in terms of the Green Transition is quite another.

Table 110. Top countries (of funded organisations) in projects of the case study CCA.

Top 15 country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Order
Germany	366	918	9,7%	392 267	13%	427,3	1
Spain	335	1091	11,5%	351 757	11%	322,4	2
Italy	310	936	9,9%	288 771	9%	308,5	3
United Kingdom	305	746	7,9%	282 972	9%	379,3	4
France	296	705	7,4%	224 512	7%	318,5	5
Netherlands	270	620	6,5%	266 271	9%	429,5	6
Belgium	265	551	5,8%	168 997	6%	306,7	7
Greece	165	376	4,0%	115 599	4%	307,4	8
Austria	162	255	2,7%	81 775	3%	320,7	9
Sweden	160	276	2,9%	112 754	4%	408,5	10
Finland	140	267	2,8%	101 096	3%	378,6	11
Portugal	137	272	2,9%	71 985	2%	264,6	12
Switzerland	135	188	2,0%	46 633	2%	248,0	13
Norway	130	276	2,9%	141 113	5%	511,3	14
Denmark	120	222	2,3%	76 360	2%	344,0	15

Source: Science Metrix, 2022, based on eCorda data

The results of a network analysis based on the number of project collaborations among organisations from different countries reflect those of the country-based analysis: there is a core group of organisations whose members predominantly collaborate amongst themselves – this group is mainly comprised of organisations from EU-14 countries (see table above).

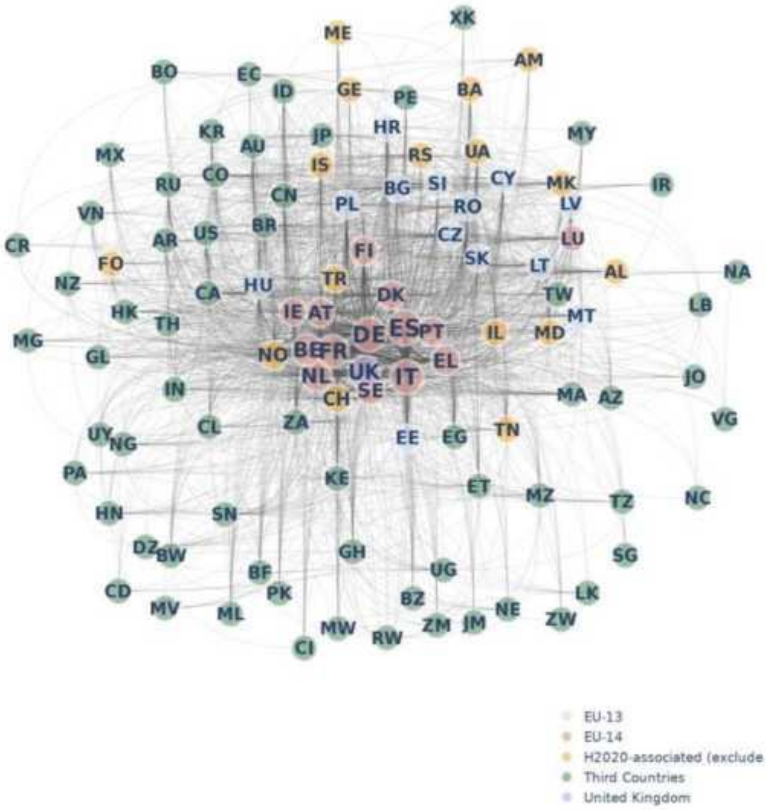


Figure 256. **Network of participating countries (of organisations) involved in funded projects relevant to CCA.**

Source: Science-Metrix, 2022, based on project data from eCorda

13.3.3.5. Results of the Horizon 2020 funding activities: pathways to impact

This section presents the results of the H2020 funding activities for different pathways to impact. Although policy documents included a pathway on market & business, CCA projects focus mainly on climate change adaptation-related research and only to a small degree on this pathway. An exception may be topics like water management or climate-resilient infrastructure, which show an increased involvement of private sector actors. As a whole, though, the focus lies on the pathways shown in Figure 276.

Coordination & Collaboration	Knowledge & Capacity	Technology & Innovation	Policies & Standards
Strengthening of EU MS, regional, and local actors Increased collaboration between sectors. Alignment of climate goals and efforts Foster inter and transnational collaboration Continuing fostering of existing research networks.	Improved understanding of CCA challenges and solutions. Improved risk and impact assessment knowledge and tools, especially on the local level. Building and provision of climate services Contribution to high-quality assessments and monitoring (IPCC).	New or improved technologies, services, or processes. Proof of concept/feasibility Demonstrators of solutions available to a wide range of actors (incl. business/industry and society).	Improved decision-making on CCA, disaster planning and response, resilience, Alignment of strategies (MS, national, regional, local) Mobilisation of actors. Sectoral alignment Improved use of existing climate research and services.

Figure 276. CCA pathways to impact.

Source: ZSI, 2022, based on H2020 WP and project descriptions

13.3.3.6. *Coordination & Collaboration*

Coordination and collaboration among quadruple helix stakeholders became considerably more important with H2020, compared to FP7, more so for CCA as a multitude of actors is involved in undertaking all the actions needed for society to become resilient to climate change and for substantially contributing to the Green Transition. This entails a vertical dimension which includes policymakers, research funders, public administrations, etc., at various levels (EU, national, regional, and local), i.e. the coordination and collaboration between these levels, as well as a horizontal dimension in that these actors coordinate and collaborate on an international, interregional, and inter-community level. Academia and research-performing organisations, businesses, and civil society organisations are involved in both kinds of dimensions.

The support and need for coordination and collaboration is reflected in the participation of cities especially. For instance, the city of Lisbon (PT) was involved in 8 funded projects, Milano (IT) in 6, Berlin (DE) in 6, Hamburg (DE) in 5, København (DK) in 5, Torino (IT) in 4, nine cities in 3 projects (incl. Genova (IT), İzmir (TR), Leuven (BE), Utrecht (NL), Sofia (BG), Aarhus (DK), Malmö (SE), Bilbao (ES), Dublin (IL), and Antwerp (NL), 34 cities across Europe were each involved in 2 projects, and many more cities in 1 project.

While H2020 considerably contributes to coordination and collaboration, interviewees concluded that – latest – with the start of Horizon Europe and its mission-oriented approach, a much bigger effort is needed, even more so to realise the Green Transition. This effort ought to consider (a) how it can activate previously unengaged (or little engaged) players, especially from the private sector and public sector and (b) how the Commission needs to re-organise to lead and govern the Green Transition.

13.3.3.7. *Knowledge & Capacity*

The project portfolio mainly contributed to improving the understanding of CCA challenges and solutions, improving risk and impact assessment knowledge and tools, especially on the local level, and building and provisioning climate [adaptation] services. The contribution to IPCC was mentioned, specifically in particular the contribution to high-quality assessments and monitoring.

H2020 projects have been successful and instrumental in creating climate services that provide high-quality information. However, an interviewed Commission expert emphasised that climate [adaptation] services are critical for CCA in general and for assessing risks and determining the appropriate strategic response, which is why instead of trying to push those services towards commercialisation, the Commission ought to make a strong effort for them to be treated like a public good, i.e. to become free and publicly accessible, like meteorological data/weather services.

Transdisciplinary research and the emphasis on co-creation, both of which follow a participatory approach with non-academic actors (e.g. citizens, societal actors, or business representatives), were taken up and contributed to the co-production of new knowledge and services. The exchange of knowledge exchange and good practices/lessons learnt have become the norm, but a systemic, transformative approach, including the transformation of institutions and more governance-related knowledge, would also be needed to substantially contribute to the Green Transition.

13.3.3.8. *Technology & Innovation*

In terms of the technology and innovation impact pathway, the funded CCA-related projects contributed towards creating new or improved technologies, services, or processes and providing proof of concept or proof of feasibility. It would be of interest to assess how many of the created services and products continue to exist or even thrive after the termination of their project; in this regard, funded projects have not performed well in the past. The difference to those is, though, that the newer services and products have often been co-created with the end users. Therefore, it can be expected that they cater to the needs of their users and thus have value and their continued availability of high interest.

Furthermore, the calls included the creation of demonstrators of new or up-scaled solutions. Making solutions known and available to a wide range of actors – like business/the industry, communes, or societal actors – is critical in boosting adaptation efforts on the ground. The EU Mission on Climate Change Adaptation continues in this vein, so H2020, to some extent, provided a fertile ground for such actions.

13.3.3.9. Policies & Standards

With regard to the policies and standards impact pathway, the project portfolio worked towards supporting improved decision-making on CCA, especially with regard to R&I policymaking – on the EU and national level. Additionally, it contributed to an improved alignment of EU 'regions and communes' needs in terms of disaster planning and response and helped increase their capacities and resilience. Projects contributing to these outcomes were mainly engaged in providing evidence based on observation systems, sometimes combined with new technologies, such as AI (e.g. CLINT – CLImate INTelligence[150]), through scenario-planning with national, regional, or local actors (like HABITABLE[151]), or through creating actionable solutions (e.g. CONEXUS[152]).

The funded projects also worked towards contributing to and improving the alignment of strategies on the MS, national, regional, and local levels, as well as with regard to the mobilisation of actors required to realise the Green Transition. However, what is still needed is a much tighter alignment of sectoral policies; without this kind of alignment and activation of groups of key actors in each sector, the Green Transition may not get off the ground. This largely applies to other case studies as well, which is why the main report discusses the matter in more detail.

13.4. Conclusions

13.4.1. Relevance

EQ 1.1 How relevant has the Framework Programme been in this area, given the stakeholders' needs and considering the scientific, technological and/or socio-economic problems and issues identified at the time of its design and over time?

Climate action, the environment, resource efficiency, and raw materials were rated by the Horizon 2020 impact assessment as a major societal challenge back in 2011. The Interim Evaluation for SC5 confirmed this and noted that the challenge was even higher up on the agenda. The compulsory nature of the Paris Agreement and of global climate objectives to limit the adverse effects of climate change and environmental impacts were also set by the Sustainable Development Goals (SDG), which went further hand in hand with the development of SC5 Work Programmes. The Green Deal especially became an integral part of the latest H2020 Work Programme that effectively constitutes the bridge between the 8th Framework Programme (FP) and Horizon Europe.

The shift from FP7 to FP8 meant pursuing a systemic approach, in combination with funding mainly impact-oriented projects to affect adaptation on the ground. These approaches can be regarded as a notable achievement, even though they initially posed a problem for traditionally strong and central players who, with the new FP in place, had to first realise that a paradigm shift was taking place. The key to success was to bring in new players to satisfy the increasing need for stakeholder engagement and co-creation approaches.

In terms of stakeholders' needs, it depends on which combination of stakeholder groups and needs are being considered – if it is providing climate services, then the FP can be regarded as highly relevant; if, by contrast, it has to do with the need to mobilise a multitude of actors (different sectors, different levels - EU, national, regional, local, etc.) and the required coordination among those, as was increasingly the case, then the FP has followed a participatory and transdisciplinary approach; however, the implementation of *collaboration & coordination* has been lacking in a sense, from a Green Transition point of view which would require close ties between, e.g. EU-funded research and MS-funded research, to boost the uptake of results.

Another concrete, noticeable development was the move towards the provision of services and the inclusion of organisations led by the private sector. The project portfolio seems satisfactory as it comprises a good mix of competent actors and can showcase successful products in climate services.

[150] Extreme events detection, attribution and adaptation design using machine learning
[151] Linking Climate Change, Habitability and Social Tipping Points: Scenarios for Climate Migration
[152] CO-producing Nature-based solutions and restored Ecosystems: transdisciplinary neXus for Urban Sustainability

EQ 1.2 To what extent have the supported thematic areas taken into account the latest technological, scientific and/or socio-economic developments at the national, European and international levels? What are the emerging needs in this area that the Framework Programme has not covered?

The thematic area of CCA is necessarily broad; however, the situation is vastly different in groups of MS/AC in terms of awareness, strategies, and actions. While the EU-14 tend to align well, generally speaking, the EU-13 often lack the capacity to stay abreast with the former group.

With regard to international collaboration, a broad range of actions across the full thematic spectrum has been pursued, aligning relevant thematic areas in the scientific and political spheres. Collaboration needs are perceived not so much in terms of a further widening of the thematic scope but more in terms of coordinating and – dramatically – accelerating the Green Transition, which is true not just for *Adaptation* but for other parts of the FP as well, as the other case studies show.

EQ 1.4 To what extent has the Framework Programme in this area addressed the needs of groups targeted for application/participation in terms of tools and thematic areas covered? Are the activities as they exist today appropriate to address the needs? What is missing?

With stakeholder engagement and co-creation in the focus of policy, a constellation of new players was needed in funded projects. Established organisations failed early on but adapted quickly to the new paradigm. In terms of boosting the engagement with non-academic stakeholders, researchers have gone further than other stakeholder groups responsible for scaling up adaptation efforts, in particular businesses/economy and politics. These are, in particular, called to action, the latter to set the right framework conditions (laws, regulations, and policies to ensure the activation of the private sector), the former in doing their part in bringing about the Green Transition.

As part of the grand societal challenges, CCA is regarded as globally relevant. A collective effort on a global level is, therefore, not just a must with regard to the much-needed transition but also mutually highly beneficial in economic terms. Europe is well placed to exert normative pressure internationally and lead by example on ambitious adaptation responses and further widening international cooperation in research and the alignment of policies.

13.4.2. Coherence

EQ 2.1 How coherent has the Framework Programme been with respect to deliver impact in the area of Green Transition, in particular: between Framework Programme parts covered by this study with other parts of the Framework Programme not covered by this study with other EU programmes serving similar objectives with relevant national, regional or international initiatives?

CCA is coherent with respect to Green Transition topics and the alignment of policies. The Green Deal served as a catalyst for new dynamics – even though new topics were not necessarily included, their relevance grew. CCA is also coherent with other parts of the FP relevant to the Green Transition. However, there is room for improvement for an enhancement of inter-DG collaboration/coordination, for example, with regard to a policy, legal, and business framework for implementation that is able to coherently encompass all MS and their specific contexts (for coordination, research, and implementation).

13.4.3. Efficiency

EQ 3.1 How efficient have the implementation processes of the Framework Programme in this area been in terms of 1) administration & management, 2) project application and selection processes, 3) funding allocation, 4) forms of implementation (e.g. partnerships, collaborative research, blending, bottom-up/top-down actions)?

Implementation responsibilities went from DG RTD to Executive Agencies (e.g. EASME); while this seemed to work well in that the latter met their targets, there may have emerged an issue of over-efficiency. This pertains to the fact the funding amount per project grew, mainly due to the fact that administrative costs needed to come down (budget cuts) while the burden on the staff increased. The “solution” may be efficient, but there are downsides that might hurt in the medium to long term. For instance, the lack of resources (mainly time and budget) to engage with funded projects (thematically, informative with regard to updating existing or formulating new policies; professionally, for maintaining or enhancing networking with key stakeholders).

It is also not clear, as of yet, how the generation of bigger projects performs as a whole, as there is an increased risk that they are not well integrated with each other.

EQ 3.2 How did these processes cater for flexibility needs in implementation? What have been the barriers or drivers? How could they be improved, or what else could be done to maximise the benefits of the Framework Programme implementation in this area? To what extent have the programme implementation processes in this area influenced the types of projects selected?

With the ongoing evolution of H2020, especially with the Green Deal and the period leading up to Horizon Europe, the critical need emerged to mobilise a multitude of actors (different sectors, different levels – EU, national, regional, local –, etc.), we well as the need to coordinate among those actors. Although the latest H2020 Work Programme and the first ones of Horizon Europe (and in particular for the Missions) catered to that need, at least from a programmatic point of view, the need for internal structural changes at the Commission was largely absent. There is a need to put adequate organisational structures in place and set up the instruments required to manage this kind and magnitude of mobilisation and coordination.

13.4.4. Effectiveness

EQ 4.1 What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results all together leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

The shift from FP7 to FP8 meant funding mainly impact-oriented projects to affect adaptation on the ground. This solution orientation can be regarded as a notable achievement, even though it posed a problem for traditionally central players initially, as they had to realise that a paradigm shift was taking place. The key to success was to bring in new players to satisfy the increasing need for stakeholder engagement and co-creation approaches. A noticeable development was the move towards the provision of climate services and the inclusion of organisations led by the private sector. The project portfolio seems satisfactory as it includes a good mix of competent actors and good products in climate services.

EQ 4.2 Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and longer term? Are there any factors that are more or less effective than others, and if so, what lessons can be drawn from this?

Cities, not just in Europe but around the globe, have become highly dynamic in the past two decades, much more so than countries on a national level. Many cities and communes want to become climate-neutral around 2030, and focusing on collaborating with them may be a more efficient way to reach CCA goals and, consequently, in bringing about the Green Transition. Moreover, co-benefits of the Green Transition are very relevant, i.e. many adaptation measures also benefit mitigation efforts,– e.g. reducing the heat island effect and supporting water retention while providing a carbon sink and improving air quality. Putting the spotlight on co-benefits may also boost collaboration with the private sector.

While one interviewee highlighted that to increase the impact of climate (change) services and create benefits for a broad base of stakeholders, such services should be made available freely and publicly accessible and similar to weather services, adaptation is noted as a broad topic, and it includes some provision of publicly available knowledge and data.

EQ 4.4. To what extent has the Framework Programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?

Some interviewed experts recognise that, although the SDG ought to be high on the agenda, there is no systematic monitoring in place. As a consequence, some Commission staff may be aware of the evidence, e.g. provided by funded projects – some of it merely anecdotal –but systematic evaluations are unavailable. Monitoring should be put in place for future evaluation efforts. While this is true for other Societal Challenges as well, this is especially true for *Adaptation*, as the United Nations Development Programme showcases on a dedicated website[153]. Adaptation solutions are often not being scaled out or scaled up for several reasons: lack of public awareness and understanding of the need for adaptation, lack of political will, sufficient funding, etc. –continuous monitoring would provide a solid base to counter some of these barriers and further allow to determine the contribution to the SDG.

13.4.5. EU-added value

EQ 5.1 What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed? Could the stakeholders have implemented their research and innovation in another way, including through other national or regional support?

H2020 considerably drove the political agenda and supported the provision of key services, especially policy initiatives. Moreover, the FP boosted participatory engagement and cocreation with key stakeholder groups – along the quadruple helix – and thus created transdisciplinary competencies that are often not found on the national level. While overall a benefit and necessary to realise the Green Transition, the absorption capacities of EU MS are often not given in terms of fostering follow-up activities on the national or regional level. This may also be attributed to the excellence-based understanding of scientific research and career models, which are stuck in the publish & perish paradigm that leaves little space for transdisciplinary endeavours.

13.5. Annexes

13.5.1. Analysed Horizon 2020 calls

As argued in the introduction of this study, the scope of *adaptation* includes calls not just from SC5 but selected ones from SC2, SC3, SC4, and certain other actions (see table below).

Table 111. Overview of analysed H2020 calls.

Work Programme	SC	Calls	No. of projects analysed
2014-2015	SC5	Blue Groth; Digital Retailing Solutions; Energy Efficiency; Waste Prevention and Management; Water in Circular Economy	131
	SC2	Blue Groth	1
2016-2017	SC5	Blue Ggrowth ;; I nnovative Industries and Services for a Low-Carbon Economy ; L eadership in Enabling and Industrial Technologies ; , S Secure, Clean and Efficient Energy ; Sustainable Food Security	102
	SC2	S ustainable Food Security	1
	SC3	Energy Efficiency	4

[153] UNDP website on SDG integration: https://sdgintegration.undp.org/integrated-solutions [last access: December 2022]

Work Programme	SC	Calls	No. of projects analysed
	SC4	Mobility for Growth	1
2018-2020	SC5	Low Carbon and Climate Action ; Space	168
	SC2	Blue Growth; Rural Renewal ; S ustainable Food Security	14
	SC3	Low Carbon Energy Systems and Smart Cities and Communities	3
2020	SC2	Bio-Based Industries – Joint Undertaking ; Low Carbon and Green Development	2
Other actions	SC5	Ad-hoc (2014-2020); Innovative Business Models ; Joint Undertaking – Fuel Cells and Hydrogen	24
	SC4	Single European Sky Air Traffic Management Research	1

13.5.2. Conducted Interviews

Table 112. Overview of interviews conducted with key experts.

Name	Organisation
Philippe Tulkens	RTD, B3, head of unit
Katarzyna Drabicka	DG RTD, B3, team leader
Franz Immler	DG RTD, B3, head of sector
Alessia Pietrosanti	CINEA, project adviser
Lydia Gonzalez	CDTI
Wouter Vanneuville	EEA, CLIMA-ADAPT
8 ancillary interviews with experts from national funding agencies, ministries, policy advice, and programme evaluation	Austrian Federal Ministry for Climate Action (BMK), Climate and Energy Funds Austria (Klima- und Energiefonds), programme evaluators from Technopolis Group, Fraunhofer ISI, PROGNOS; evaluation chair KLIMAFORSK; Research Council Norway

14. Case study 14: Nature-based-solutions[154] – innovation in support of natural resources and ecosystems

14.1. Summary

This case study has focused on H2020 funding for NBS R&I to identify and analyse relevant actions related to Nature-based Solutions (NBS) in Horizon 2020 and respective partnerships (i.e., JPI CLIMATE, JPI Urban Europe, JPI Oceans, etc. and linked ERA-NET, such as BiodivERsA). The thematic scope of the case study comprises the following areas: 1) ecosystem services, 2) biodiversity actions, 3) and greening, including climate adaptation/mitigation.

The NBS theme sparked off, particularly with the international framework changes in 2015 (Paris Agreement, SDGs, etc.) and since then has increased in relevance over the second half of the H2020 Framework Programme. For the analysis of this case study, we first reviewed a major academic publication from August 2022 (Al Sayah, Versini, and Schertzer 2022) that explicitly evaluated the NBS H2020 R&I portfolio and trajectory from an interdisciplinary vantage point, based on 21 sample projects. Second, we conducted 9 interviews with various stakeholders and analysed a total of 38 projects, partly overlapping with the academic study and partly additional projects, selected for their scope and relevance, under 4 calls tackling Societal Challenge Area 5, with high relevance to the case study.

It has been found that Horizon 2020 has ensured that by directly drawing on important precursors in the field of ecosystem approaches and eco-based restoration, important steps towards more coherent NBS community establishment, including mutual learning, stock-taking and decision support actions, were set. Importantly, in recent years a more holistic, more policy-coherent view of NBS started to emerge in the Horizon 2020 calls that, under the impact of the Covid-19 pandemic and climate change, shifted NBS thematic attention essentially towards NBS predominantly focusing on climate adaptation. This is referred to by Al Sayah, Versini, and Schertzer (2022) as “NBaS” (Nature-based Adaptation Solutions), particularly in urban environments. The results of the NBS Horizon 2020 projects analysed under this study, as well as those by Al Sayah, Versini, and Schertzer (2022), are generally positive: they have paved the way to global agenda-setting and leadership with regard to NBS but also led to more novel NBS tool, network and knowledge platforms with relevance to the business and public urban administration level. On a material level, new insights have been explored with regard to NBS-inspired sustainability techniques and technologies with regard to maritime environments, drought and flood handling, and thus fostered disaster risk reduction. At the urban level, Horizon 2020 projects supported the exchange of best practices. However, there are shortcomings with regard to thematically linking NBS further to key climate resilience and green transition areas, such as agriculture (including urban food supply), energy and transport, including the systemic policy frameworks.

In addition, NBS participation has been virtually absent in the EU-13 countries and, to a large extent, focused on research institutions, thus evidencing a notable gap with regard to developing a coherent policy, legal and business framework involving all member states.

As a qualitative assessment through our interviews, an important area of improvement for the next Framework Programmes concerns more coherent and well-aligned communication between DG RTD, DG CLIM and DG ENV, on the one hand, and DG REGIO, DG ENER, DG AGRI with DG RTD, on the

[154] The Commission defines nature-based solutions as: “Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.”
Nature-based solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services.

other: together with setting NBS as a transversal, cross-cutting issue, and involving lighthouse projects, this would be crucial to increase the relevance and coherence of next calls with existing and coming NBS policies, also beyond NBS focusing on climate adaptation. Another area of improvement would be the extent to which policymakers in DG RTD and other DGs are updated on the results of the Horizon 2020 projects, which could be useful to feed into their policies to make those more coherent with innovative public and private NBS-informed businesses models.

14.2. Introduction and overview

14.2.1. Objectives of the case study

The case study identifies and analyses relevant actions related to Nature-based solutions in Horizon 2020 and respective partnerships (i.e., JPI Urban Europe and linked ERA-NETs). It provides, on the one hand, an assessment of the implementation of the Horizon 2020 funded projects in this area, on the other of the extent to which the portfolio design, projects, networks and policy uptake have effectively contributed to the overarching goals of the green transition and the Green Deal. Furthermore, Horizon 2020 provided a strong basis for developing and progressing the Horizon Europe Missions for a Climate Resilient Europe and Climate Neutral and Smart Cities, as well as the oceans and soil missions. Against this background, the main objective of this case study is to analyse to which extent Horizon 2020 actions enabled an effective approach for forwarding Nature-based Solutions that can be further scaled up in Horizon Europe.

14.2.2. Scope and methodology of the case study

The analysis comprised 22 Horizon 2020 calls (of which 8 SC5 calls) & 1 ERA-NET. The time horizon covered with the analysis is 2014 – 2020, but more importantly, 2018-2021 since most calls started off under the respective Work Programme. The number and type of instruments analysed are, for the quantitative and qualitative assessment, 14 RIAs, 5 CSAs, 19 IAs and 1 ERA-NET. An overview is provided in the Annex of this case study. For the content-related assessment, a list of 21 major projects has been selected, following the approach taken by Al Sayah, Versini, and Schertzer (2022).

The analytical approach (Figure 92) commenced with a thorough analysis of work programmes, relevant call texts etc. and strategic documents related to Nature-based Solutions (e.g., the expert reports from 2015 and 2017). We then identified relevant project actions in Horizon 2020 based on a keyword search of topics in the work programme and an analysis of the information portal of OPPLA and Cimate-ADAPT. For the identified projects, relevant data as available from Cordis/Corda have been compiled, analysed, and complemented by additional sources, such as project websites.

In addition to the project data analysis, we performed 9 interviews with relevant stakeholders. The interviewees comprised representatives of thematic experts involved in the European strategic processes, representatives of EU agencies, European Bauhaus, research beneficiaries and offspring platform representatives, as well as national experts (in particular from Spain, the second largest beneficiary country in the field). The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus.

To obtain the following results and conclusions for this study, we conducted, in addition, the following methodological steps:

A. Document review, including EU expert reports, as well as some recent journal articles focused on the H2020 NBS research projects' scope.
B. Quantitative bibliometric analysis with regard to efficiency and effectiveness in terms of portfolio performance and (preliminary) output.
C. A series of semi-structured interviews with 9 international experts from several DGs, EU agencies and related NBS researchers.
D. Sample review and corroboration of previous findings (Al Sayah, Versini, and Schertzer 2022) from a selected list of H2020-funded NBS projects

For synthesizing the analysis, we triangulated and analysed the findings in relation to the evaluation questions.

14.3. Synthesis of evidence

14.3.1. A green transition with, not against, Nature

NBS present today for Europe the main innovation-centred backbone or "main revolution" (in the words of some experts in the DG RTD interviewed for this case study) for operationalizing the re-naturalization of city spaces, climate change adaptation and resilience strategies, or in other words, for effectively bringing about the Green Deal and the Green Transition. The EU has actively supported environmental research since the start of its Framework Programmes for Research and Technological Development (FP). According to Faivre et al. (2017, 509), "These programmes had an initial emphasis on biodiversity assessments, better-understanding ecosystem structures and functioning, and on assessing ecosystem services and the vulnerability of these ecosystems to stressors. The framing of research within a socio-ecological framework as of FP6 (Sixth Framework Programme; 2002–2006) is evidence of the progressive integration of social and political sciences."[1]

Figure 257. Integral Ecosystem-based Approach to Societal Challenges.

Source: IUCN, 2020. Global Standard for Nature-based Solutions: first edition. Gland Switzerland: IUCN

Horizon 2020-funded NBS research set out to establish, render proof, collect, and compile the relevant interdisciplinary and transdisciplinary knowledge and network bases across policy, community and private stakeholders. Arguably, this has been effectively achieved (projects under WP 2018-2021 have not been terminated yet) by establishing a broad portfolio and realizing several flagship projects in the field, such as OPPLA, Connecting Nature, Nature4Cities, etc. A focus on urban spaces has been inherent since urban NBS served as a broad and contested umbrella term, referring to key mechanisms in the global fight against climate change, thus addressing large parts of the population. Therefore, their focus is on cities and urban landscapes, which have an enormous footprint by consuming over 65% of the world's energy and accounting for 60%-80% of global CO_2 emissions, depending on the estimates.[1] In Europe, cities take up only 4% of the EU's land area, but they are home to 75% of EU citizens.

NBS build on the ecosystems approach that has been used since the 2000s. It advocates the integrated management of land, water, and living resources and promotes their conservation and sustainable use in an equitable way (COP 5 Decision V/6). The strength of the concept of NBS is its integrated perspective for addressing societal challenges. Ecosystem services are the contributions that ecosystems, in combination with other inputs, make to human well-being. Nature-Based Solutions

operationalize the concept of ecosystem services in real-world situations to **promote sustainability** more explicitly. NBS also play a critical role in promoting **'transitions'** from a resource-intensive growth model towards a more **resource-efficient, inclusive and sustainable** growth model – whether such a silver bullet can actually be conceived remained largely outside Horizon 2020s applied R&I scope. Transitions are **radical innovations** in structures, mindsets and practices that involve actors from different sectors, domains and scale levels in the co-design and co-implementation of solutions.[2]

Yet there are still knowledge-related voids and blind spots with regard to interdisciplinary knowledge – e.g., on the interdependency and transversal impacts across micro ecosystem variants – policy implementation and funding, but also research uptake itself, which need to be addressed in Horizon Europe. A major point in case is the (almost entire) **absence of rural agricultures** in H2020-funded NBS research in **SC5**; another one is the (as of yet) missed uptake of NBS research insights within the Commission and the way the FPs are designed (including their incentives for increased resource efficiency). However, to be effective and relevant, NBS would urgently require improved multilevel governance coherence, broad thematic and actor involvement, particularly amongst member states, academic systems and institutions, EU FP funding, EU agencies, and their dissemination activities, in short: encompassing collaboration at all societal sector levels, as illustrated below.

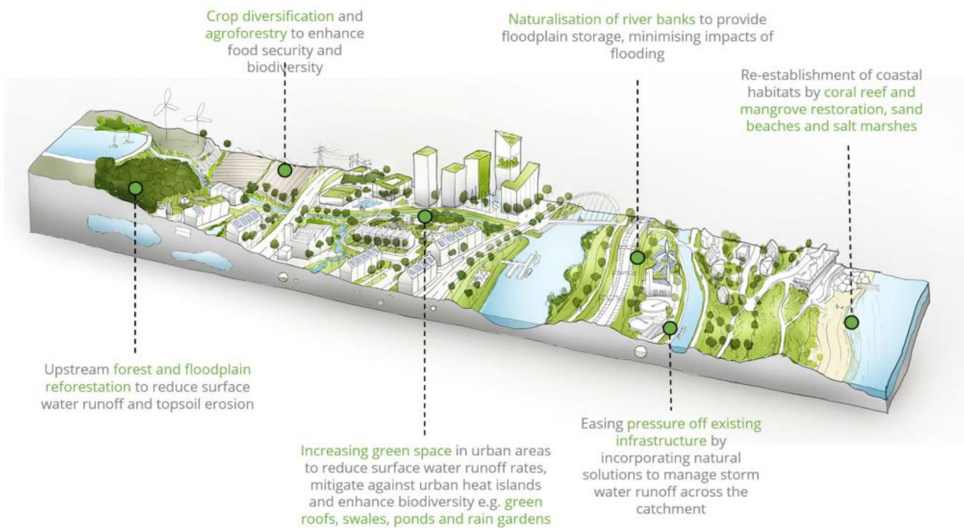


Figure 258 Coherent cross-regional NBS implementation.

Source: Infrastructure Pathways, 2022.

This study thus presents a conjoint state-of-the-art review and vision of the field and links, in particular, to climate action more broadly.

14.3.2. *Strategic policy priorities related to a green transition by means of NBS*

According to Al Sayah, Versini, and Schertzer (2022), the adoption of the UNEA resolution can be seen as an outcome of the EU-funded effort in the field since the EU expert report from 2015 and a generally friendly policy environment since then: “In 2015 and 2016, four major global policy agreements were adopted at the United Nations (UN) level: the first was the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030, adopted in March 2015 (UNDRR, 2015); the second was the endorsement in October 2015 by the UN General Assembly of the 17 Sustainable Development Goals (SDGs) (UN, 2015); the third was the Paris Agreement on climate change, adopted in December 2015 (UNFCCC, 2015); and the fourth was the new urban agenda, adopted in October 2016 and endorsed by the UN in December 2016 (UN, 2017)”.[2]

At the moment of carrying out this study, NBS clearly have the policy momentum on their side required to induce transformative change: IUCN pioneered NBS approaches in the early 2000s and, in July 2020, published its Global Standard.[3] This standard includes guidance (with eight criteria and 28 indicators) and a self-assessment tool, and it provides a common understanding and consensus on NbS to accelerate the scaling up of proven and workable models of NbS for both mitigation and adaptation"[1] [2]. According to the IUCN, Nature-based Solutions have significant yet currently underutilised potential to help address global challenges. In addition, the World Bank has employed this concept since 2008, the Climate Summit in the US included NBS widely (also 2019), and there are joint proposals by several EU DGs underway that initiated and fostered collaboration around NBS (e.g., DG CLIMA, ENV, REGIO, etc.). This all points into the direction of multi-level, cross-sectoral policy frameworks which need to be developed in order to implement economy-positive NBS as a veritable paradigm shift:

"Many policy frameworks and processes in the EU (e.g., European Green Deal, EU Biodiversity Strategy 2030, EU Adaptation Strategy 2020, EU Nature Directives) and globally (e.g., forthcoming CBD Post-2020 Global Biodiversity Framework, Edinburgh Declaration, UN Decade of Ecosystem Restoration) call for multi-level, whole-of-government policy frameworks. The potential for alignment of NBS with other policy fields is vast. Policy areas of high priority for NBS integration next to Environment include Climate, Economy, Energy, Planning, Digital Europe, Health and Social Policy."84

Moreover, the scientific community consolidated around the umbrella concept of NBS; scientific publications are mushrooming, not least due to H2020 funding (see below for more details). More recently, NSB fed into the evolvement of new policy frameworks such as nature-positive concepts and solutions and the Global Biodiversity Framework at the UN, discussed at COP27 and COP15, heavily promoted by EU delegations. In a joint effort, eventually, DG ENV and CLIMA started to work on updating future technical standards and measurable indicators, including an important stocktaking exercise.

Summarising, the overall ambition of the existing high-level policy strategies related to a green transition by means of NBS addresses the largely unexplored potential to deliver a viable route to a nature-positive economy that, ideally and simultaneously, generates a multitude of benefits while promoting and safeguarding biodiversity remains at the centre of a nature--based approach. The large-scale investment in NBS needed for transitioning to a nature-positive economy must carefully balance –if possible, at all - the vast potential to harness nature for economic development and job creation with **equal respect for the voice of communities**, **culture**, and **traditions** and above all, lead to the **restoration of natural resources** and **biodiversity**.

Throughout the strategic documents analysed, the necessity of a collaborative approach that fosters societies' NBS capacities in its effort to combat climate change and increase liveability is mentioned. Notably, these key policy strategies, termed by some experts as a distinctive European approach", have been developed during the runtime of Horizon 2020, which had to actively align with the new policy developments in the area.

14.3.3. Horizon 2020 programming related to Nature-based Solutions

14.3.3.1. Horizon 2020 Work Programmes Related to Nature-based Solutions

NBS objectives have mainly been present in the last triennial work programmes of Horizon 2020 and mostly with regard to SC5 Climate. Being an umbrella term that only gained track in Europe after 2015, there have been relevant mentions of NBS-related themes also in the precursory Work Programmes.

The 2014-2015 WP already included sustainability and climate action as transversal issues, focusing broadly on food security and blue growth strategies that built on themes to be understood as relevant precursors for NBS. This focus shifted over the WPs towards primarily focusing on nature, biodiversity and economy-positive transformations of urban spaces. While much emphasis was steadily put on re-naturing, greening, water supply and other areas of concern, some voids remained, in particular with regard to rural spaces and agriculture (with the exception of SC2) in a **more ecosystem-centred systemic perspective**, linked to SC5.

In the 2016-2017 WP, the circular economy has been a major concern linked to the Industry 2020 strategy. A key focus on biodiversity, food security, and blue growth was maintained, while smart and sustainable cities as a crosscutting issue entered the picture, pathing the way forward to a fully-fledged urban NBS focus in the last WP. Without mentioning NBS, WP 2014-2015 already noted that sustainable development of urban areas requires new, efficient and user-friendly technologies and services, in particular in areas of energy, transport and ICT, delivered through integrated approaches at the level of research and development and deployment.

The work programme 2016-2017 aimed at improving urban socio-economic functioning through sustainable integrated energy and transport solutions and to develop business models, innovative financing modalities and appropriate governance modes for integrated solutions[1]. The focus was on **large-scale demonstration** projects as **'living laboratories'** for deployment, testing, replication and scaling up of innovative systemic and yet locally attuned solutions aiming to help make the EU a **world leader of a new market for sustainable energy solutions** – an effective breeding ground for NBS approaches.

The work programme 2018-2020 constitutes a bridge between Horizon 2020 and Horizon Europe, in which innovative solutions for urban and coastal climate resilience are being seen as also a crosscutting concern.[2] Throughout the three work programmes, not only technological development (especially in the form of decision support tools) but also an integration of efforts and collaboration between public and private stakeholders at national and regional/city levels have been stressed. The inherent ambition of the H2020 work programme related to NBS matters was to 1) enable the creation of European urban and freshwater-related NBS strategies and 2) provide the necessary conditions for the emergence of related innovation ecosystems, and 3) to create a more integrated European market for NBS-styled sustainability solutions for cities. Overall, this pathway has been informed by the IUCN's usage of NBS, which moved it steadily closer to adaptation strategies, also reflected in European policy frameworks. In addition, the Covid-19 pandemic was a stimulus for integrating NBS into post-pandemic impulse packages. As a consequence of this transition, NBS and climate adaptation moved steadily closer together, a process that has been described as almost entirely collapsing the field of NBS into adaptation and mitigation solutions as the – by far – predominant focus to date.[1]

14.3.3.2. Summary of strategic policy priorities

Against today's strategic priority to develop a scenario of fully-fledged European climate adaptation, already Horizon 2020 and its Work Programmes aimed to contribute to a green transition. The analysis of the Work Programmes and the projects showed that distinct pathways to impact can be identified that connect the activities carried out within the work programme with identifiable effects (outcomes). Based upon the Work Programme analysis, Table 115 provides an overview of pathways to impact identified in the analysis that is to some extent similar to the one of the smart city case study since NbS projects have predominantly focused on urban settings.

Table 113. Pathway dimensions across all analysed calls.

Coordination & Collaboration	**Knowledge & Capacity**	**Market & Business**	**Technology & Innovation**	**Policy & Standards**
Internal DG coordination	*New & Synthesized Knowledge*	*Pilots and*	*Open Data & Transparency*	*Policy*

		Demonstrators		*Harmonization*
City to City	*Monitoring & Evaluation*	*Upscaling & Repetitions*	*Risk Reduction*	*Regulatory Frameworks*
Quadruple / Quintuple Helix	*Local Context Sensitivity*	*User Involvement*	*Advanced Adaptation*	*Legally binding Frameworks*
Project to Project	*Institutionalized Inter-and Transdisciplinarity*	*Business Plans and Models*	*System Integration*	*Coherence*
Across Member States	*Learning & Training*	*Financial regulation and funding*	*Sectoral Services*	*Transparency*

Source: own elaboration.

The **coordination and collaboration** pathway highlights the increasing importance of coherently coordinated and well-orchestrated collaboration between different stakeholders, including DGs within the EC, but also with regard to member states and EC, as well as researchers to city and municipal authorities and companies implementing NBS. In addition, by its very nature, NBS and NBS with an adaptation focus need to be immensely local context relative and sensitive, but also with regard to transforming traditional research disciplines and geographical scope. In the urban context, the ambition was to facilitate trans-disciplinary collaborations between different types of stakeholders through city-to-city, project-to-project, and international cooperation actions. Yet NBS will not stop there and are rather dependent on urgent expansion beyond cityscapes, for instance, with regard to food production and supply.

The **knowledge and capacity building** pathway relates, on the one hand, to the need to develop new knowledge, innovations and methods, in particular by including the natural sciences and long-term observations regarding ecosystems' interdependencies (see Al Sayah, Versini, and Schertzer (2022), as well as frameworks for the systematization of data and enabling legally binding decision support. To achieve the latter, the social sciences with a focus on transition governance, especially bringing different stakeholders together and to achieve social NBS-based innovation acceptance need to be fostered. On the other hand, the need for dedicated capacity building & training activities amongst different target stakeholder groups is underscored. Likewise, monitoring and evaluation for the development of broadly accepted NBS indicators and establishing learning frameworks for improving decision-making support and local governance also played an integral, yet so far less explored, part.

The **market & business** pathway emphasizes greater and more coherently steered involvement of public and private actors and a focus on pilot and demonstration activities to test solutions in practice and to follow a need and demand-driven approach. Marketability and bankability of NBS require fostered and concerted dissemination beyond Agencies, as well as financing, insurance and tax related as well as legal frameworks in order to achieve the necessary stable funding requirements. This should be supported for generating interest among market actors. Demonstration and pilot activities should facilitate an ecology-positive, long-term transformative impact, increased funding visibility, and adapted legal and financial frameworks, especially at the MS level, and moreover, in the post-2013 EU countries, to enable upscaling and repetition.

The **technology and innovation** pathway emphasizes the importance of improving overall services in cities and coastlines (and beyond) by means of developing integrated ecosystem-based solutions (which include NBS) with supporting technology. Coherence is key: for instance, relevant sectors for European cities have so far only marginally been included (arts) or not at all (e.g., restorers, which work with historical buildings in European city centres). European Bauhaus and its take on the quality of experience for technological design solutions has been relevant in this sense. Overall, this pathway involves the deployment of a portfolio of tools, business models and technological (including social) solutions as part of a new system or their deployment and integration into any system with associated improvements in the services that these sectors provide. NBS can be framed as an umbrella pathway under which approaches to Circular Economy, Bioeconomy, Climate Change Adaptation, Ecosystem Restoration, etc., would find concrete application.

The **policy and standards** pathway emphasizes, on the one hand, the need to facilitate better adaptation and resilience planning across member states and also DGs (particularly DG REGIO, DG AGRI, and DG GROW with DG RTD and DG ENV) with regard to rural and urban policies and better institutional governance arrangements (e.g., multi-level, cross-sectoral, cross-system). Binding frameworks at the European and regional levels are highly necessary to push NBS further. On the other hand, new technical standards and standard-setting measures are needed for building interoperable technology infrastructure(s) and process frameworks for resilient and climate-adapted nature-based solutions.

14.3.4. H2020 Project Portfolio Analysis

The overall project portfolio of this case study comprises 38 projects, of which the majority of projects are just about finished between 2022 and 2024

Table 114. Type of Organisation in Case Study NbS.

Type of organisation	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1000)	EC contribution Share (%)	EC Contr. per part. (EUR 1000)
HES	35	237	25%	82 590	26%	348,5
OTH	31	109	11%	33 980	11%	311,7
PRC	34	225	24%	52 549	16%	233,6
PUB	31	165	17%	71 078	22%	430,8
REC	37	214	23%	81 149	25%	379,2
Total (All types)	**38**	**948**	**100%**	**321 346**	**100%**	**339,0**

HES: Higher or Secondary Education Establishments
PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments)
REC: Research Organisations
PRC: Private for-profit entities (excluding Higher or Secondary Education Establishments)
OTH: Other

The sum of EC's net contribution is EUR 339 Mio, of which 24% has been allocated to private companies, 17% to public bodies, 23% to research organisations, 15% to higher education institutions and 11% to other organisations. Compared to all other Green Transition areas considered in this study (SC2 to SC5), the portfolio of city projects – thematically closely linked to NBS – has the highest share of funding for public bodies (25% in the case study vs 5% in all Green Transition areas and other organisations (11% vs 6%), indicating a particularly high relevance for municipalities and regional actors (agencies, civil society representatives etc.) taking part in the calls.

Table 115. Type of actions/instruments (grouped) in case study NbS.

Group of Action/instrument	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)
IA	19	570	60,1%	223 473,2	69,5%	392,1
RIA	14	345	36,4%	90 141,6	28,1%	261,3
CSA	5	33	3,5%	7 730,9	2,4%	234,3
SME	0	0	0,0%	0,0	0,0%	N/A
Other	0	0	0,0%	0,0	0,0%	N/A
All types	**38**	**948**	**100,0%**	**321 345,8**	**100,0%**	**339,0**

With 570 participations of funding allocated to Innovation Actions (IA), the NBS study portfolio is characterised by a high degree of application orientation and a limited representation of CSAs compared with the aggregated Green Transition project portfolio, in which the share of IA is at 47,3% and the share of CSA at 7,4% of allocated funding. The portfolio highlights commitment to innovation and marketization of research results, which have also been confirmed in our interviews. Within the portfolio of instruments, specific patterns of participation of actor types occur. IAs are more densely populated with private companies, whereas RIAs have a considerably higher share of participation of

Research Organisations (REC). Public Authorities are represented in all instruments but considerably less in RIA and CSAs.

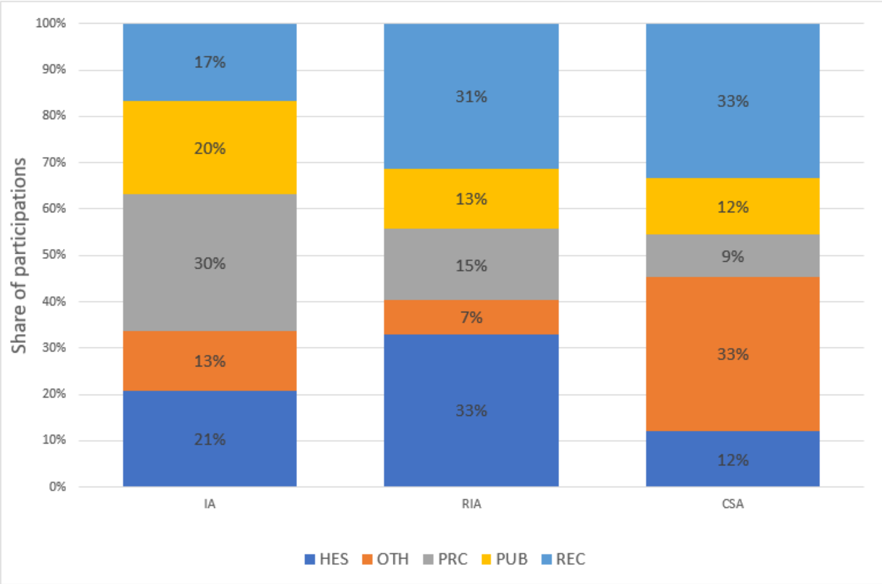


Figure 259 Share (%) of participation by type of action/instruments.

Table 116. Group of countries of the case study NBS.

Group of country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Number of countries
H2020-EU27	38	742	78,3%	265 297	82,6%	357,5	26
EU-14	*37*	*646*	*68,1%*	*239 383*	*74,5%*	*370,6*	*14*
EU-13	*27*	*96*	*10,1%*	*25 914*	*8,1%*	*269,9*	*12*
H2020-associated (exclude UK)	25	57	6,0%	19 575	6,1%	343,4	10
United Kingdom	26	72	7,6%	31 818	9,9%	441,9	1
Third Countries	21	77	8,1%	4 656	1,4%	60,5	24
All-countries	**38**	**948**	**100,0%**	**321 346**	**100,0%**	**339,0**	**61**

Geographically, the eCorda statistics show that the 38 selected Horizon 2020 projects on NBS managed to considerably open up the participation of associated countries and third countries. Associated countries (excluding the UK) have participated in 25 out of 38 projects, and 24 third countries in 21 out of 38 projects, which is considerably well compared to other samples in the field of SC5. There is still leeway to fostering international cooperation given 0 third-country project coordination in a field that, by definition, needs to look beyond geographical borders in order to address major climate-related risks and challenges. NBS-based implementations in Europe will unavoidably affect the world climate, hence the urgent necessity for international dialogue, network and research exchange. The largest gap in terms of participation in relation to EC contribution is observed for the post-enlargement EU members (with the notorious exception of Slovenia and Estonia), which participated in 3 projects and received only *1.8* % of the total budget. This is substantially more unequal compared to all Horizon 2020 Green Transition projects. In terms of participation pattern, Germany and Spain stand out with the highest share of EC contribution in total funding (13% and 11%, respectively) and Germany in absolute funding per participant, followed by the UK (10% %) and France (10,5 %) with lower EC contribution but a higher number of participations than Spain.

The participation pattern sees countries and cities that pursue ambitious NBS-focused adaptation targets and early adopters of the NBS adaptation concepts in Europe (e.g., Spain) at the forefront. On the downside, an almost inexistent rate of participation rate of EU-13 indicates a high level of exclusiveness that seems highly detrimental to utilising the full transformation potential across Europe.

Table 117. Top countries in case study NBS.

Top 15 country	Number of projects	Participations Nb	Participations Share (%)	EC contribution EUR (1,000)	EC contribution Share (%)	EC Contr. per part. (EUR 1,000)	Order
Germany	32	90	9,5%	41 210	13%	457,9	1
Spain	30	107	11,3%	35 430	11%	331,1	2
Italy	27	89	9,4%	32 318	10%	363,1	3
United Kingdom	26	72	7,6%	31 818	10%	441,9	4
France	24	76	8,0%	22 830	7%	300,4	5
Netherlands	24	64	6,8%	25 016	8%	390,9	6
Belgium	22	50	5,3%	19 141	6%	382,8	7
Austria	15	25	2,6%	9 253	3%	370,1	8
Sweden	15	20	2,1%	6 995	2%	349,8	9
Finland	14	26	2,7%	11 464	4%	440,9	10
Greece	13	25	2,6%	7 297	2%	291,9	11
China	12	23	2,4%	0	0%	0,0	12
Denmark	11	28	3,0%	11 432	4%	408,3	13
Poland	10	19	2,0%	5 946	2%	312,9	14
Portugal	10	26	2,7%	8 353	3%	321,3	15

The network analysis is based on the number of collaborations among organisations from each pair of countries in the projects included in this case study, confirming that the sustainable case study shows a high collaboration intensity among a number of core countries, predominantly from the EU-14, collaborating to a large extent among themselves.

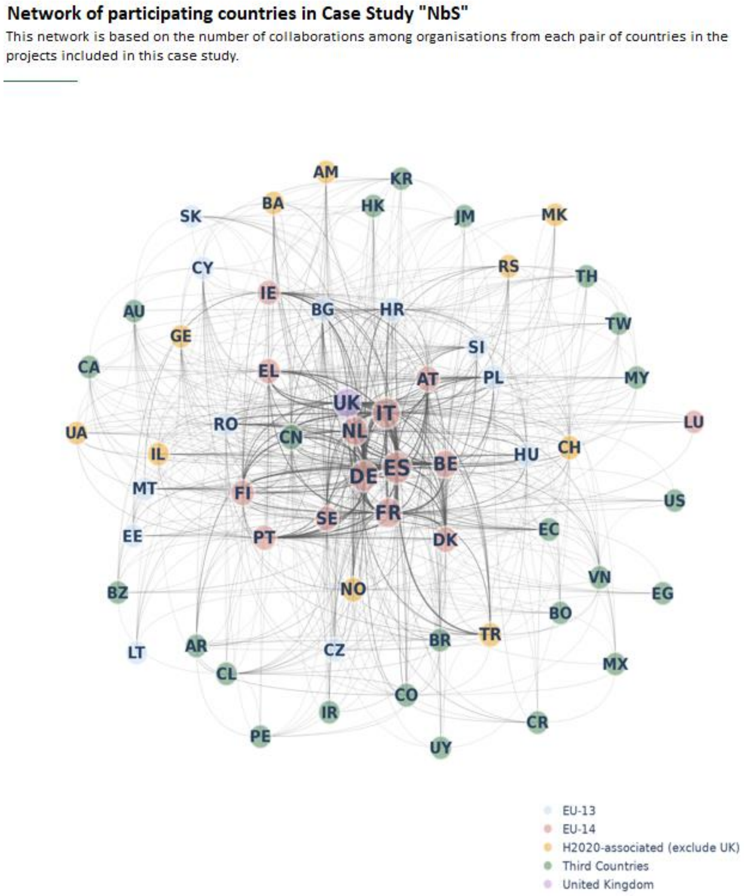


Figure 260 Network of participating countries in Case Study "NBS".

14.3.5. European Partnerships related to Nature-Based Solutions

In addition to the Horizon 2020 project portfolio and its related calls, ERA-NET CoFunds under the framework of Joint Programming Initiatives, as well as Joint Undertakings (Jus), constitute a relevant part of actions co-funded by the European Union in this case study. JPI with relevant NBS components were:

1. Bio-based Industries (BBI)
2. FACCE JPI - Agriculture, food security and climate change
3. JPI Climate - Connecting Climate Knowledge for Europe
4. JPI Urban Europe - Urban Europe - Global Challenges, Local Solutions
5. JPI Water - Water Challenges for a Changing World
6. JPI Oceans - Healthy and Productive Seas and Oceans
7. EIT Food - EIT Food connects businesses, research centres, universities and consumers.

   While in its 2020 Research Strategy, the Green Deal and contributions to the net-zero emissions by 2050 (instead of 2040) are mentioned, FACCE-JPI does not mention nor include any focus on NBS or alike.

   Under the umbrella of JPI Urban Europe, annual calls were launched addressing specific areas and priorities in the Strategic Research and Innovation Agenda of JPI Urban Europe. While NBS was not addressed explicitly, they were present in some of the projects carried out under the call **Sustainable Urbanisation Global Initiative (SUGI)/Food- Water-Energy Nexus (2016) and Sustainable and Liveable Cities and Urban Areas (2018)).**

   JPI Urban Europe followed a multi-faceted challenge-driven approach addressing complex issues and wicked challenges (urban dilemmas) to provide sustainable urban solutions and enhance knowledge, research capacity and impact of research on urban transitions[1]. It is not a programme that relies on a technology push but one that is built on the idea that the people in need in the city are the ones with whom you have to work and whose needs you have to address. Instead of a technology-driven approach, the emphasis was on 1) inter- and transdisciplinary research to improve the understanding of how socially, economically and environmentally sustainable European urban areas are and 2) the creation of new knowledge and concepts to tackle urban challenges.

   Coordination and collaboration, in particular with EU-MS, city stakeholders, other strategic initiatives and networks, international cooperation and widening participation was a key focus. In terms of project funding activities, JPI Urban Europe calls aimed to:

- **co-create ideas, concepts and solutions,**
- **create room for experimentation, share experiences, jointly test new approaches and create references**
- foster sharing resources, including integrated **urban models, datasets, urban observatories and urban living labs**;
- Develop the **understanding, knowledge, tools and evidence** to underpin the formulation of effective urban transition policies and strategies and **contribute sociotechnical innovation** to this end;
- **Explore new data sources, and big data for monitoring and evaluation**, providing a framework to monitor and assess sustainability.

More recently, and with a similar take on the blue world, JPI Oceans launched the NATURE project (09/2021- 09/2024) that assesses nature-based solutions (NBS) as a management option for water treatment on the catchment scale. The NATURE project encompasses three interconnected phases:

1. An experimental phase in which the reduction of aquatic pollutants will be evaluated in NBS and compared with reference sites.
2. In the data modelling phase, diagnostic indicators (indicative parameters from the first phase) will be identified for cost-effective future monitoring.
3. In a risk assessment phase, the effect of aquatic pollutants on the environment and human health will be evaluated, estimating its reduction due to NBS implementation.

JPI Climate has included several projects, directly and indirectly, relating to NBS and societal transformation, yet it is difficult to access and assess the information on a systematic base.

14.4. Results of the Horizon 2020 funding activities: pathways to impact

14.4.1. Coordination & Collaboration Pathway

Coordination and collaboration between different types of institutions and stakeholders (from researchers to policymakers, companies implementing NBS and legal actors providing the reliable funding environment), research disciplines and geographical extent played a considerable role in the portfolio. In particular, large projects aiming at the establishment of knowledge and interconnection platforms followed the logic of linking different themes and (mostly urban) space in terms of socio-economic determinants, size and geographical variety to address a wider range of challenges and needs across Europe.

The important role of collaboration is well recognized in the project portfolio, e.g., by peer-to-peer learning and capacity building (CONNECTING Nature and GROW GREEN). Overall, a key characteristic is that it is predominantly “outward-looking” in the sense of aiming at, and addressing, stakeholders and research/business actors outside the EC and EU agency, but also member states’ government environment. In many cases, the analysed projects created learning platforms that connect coastal areas, cities, businesses, civil society and research institutions and universities (Quadruple Helix). A necessary push towards the Quintuple Helix (including the environment as a transversal and encompassing issue in all dimensions of the quadruple helix) should be underscored and is required.

Especially in those cities and areas which are at risk due to climate change impact (e.g., Netherlands), the work programme aimed at the broad involvement of local stakeholders, including in the consortium, in order to 1) jointly develop solutions and improve the knowledge and capacity of system-actors, 2) implement and adopt solutions by relevant market participants, and, although to a lesser extent, 3) create a policy and regulatory framework that enables new standards for NBS. To this end, projects developed and employed a variety of co-creation tools and approaches to engage the Quadruple stakeholders. Yet, there has been an overweight towards the private and research sector, with less involvement of the public sector, which, however, would be crucial for the effectiveness of the green transition. The quantitative data analysis supports this argument and shows that the EC contribution is highest for the private sector and research and higher education institutions, especially in the core countries (see above).

The interviewees highlighted that the feasibility and strength of a project depend largely on the diversity of actors within the consortium, which needs to be composed already prior to the proposal writing stage and by itself binding several unfunded or reimbursed resources (a notorious challenge for smaller consortium members). However, this way, the project can ensure from the start that the solutions are co-developed and implemented later on. Similar to the smart city case, at the level of city administrations, the quality and concrete input of consortia partners remains a challenge. It was emphasized that a project consortium needs to work very closely together, build trustful relationships in order to be successful in implementing solutions and following them up. By another interviewee, it was suggested (and reappeared in others) that to be successful dissemination and outreach activities, including twinning and mutual learning from project insights across urban and regional policymakers, should, on the one hand, have access to exploratory research instruments which enable the establishment of trust relationships and the identification of concrete needs. On the other, access to post-project funding to ensure that these learning experiences become broadly followed up.

Furthermore, it was made clear that citizens are essential for successful project development and implementation and that highly participative, e.g., citizen science-based, research and innovation processes should be boldly fostered and trusted as they are seen as a key component to building legitimacy, confidence, and broad recognition, as well as for developing solutions adapted to local citizens' needs.

In terms of cooperation between projects, a representative of the European Commission noted that clusters between key projects have become very strong interdisciplinary networks. With regard to the last H2020 cross-sectoral call, the Green Deal call, projects have only recently been initiated and are difficult to assess.

14.4.2. Knowledge & Capacity Building Pathway

The projects analysed produced actionable and practical knowledge on various facets of urban and coastal environments, particularly with regard to climate change adaptation through innovative circular and ecosystem-based approaches. Largely, DG and policy-related interviewees agreed that the effectiveness of NBS, in particular for urban environments, has successfully been demonstrated and that implementation and locally sensitive upscaling would be the next step forward.

However, views from the science community differ to some extent: more knowledge would be required, in particular on the monitored interplay and interdependencies of NBS with regard to locally connected ecosystems, including urban spaces. The key would be to include more studies from the hard sciences with regard to mid to long-term effects. In addition, a more social science-informed view on the governance and institutional framework conditions of NBS would be needed for broader implementation, comparison and enabling the right policy frameworks. This, however, is complicated by the demands of inter and transdisciplinary research which Does not square easily with the traditional, single-disciplinary academic requirements of scholarly disciplines and related higher education and academic career paths in the member states. This might contribute to why NBS R&I is virtually inexistent beyond the core EU countries.

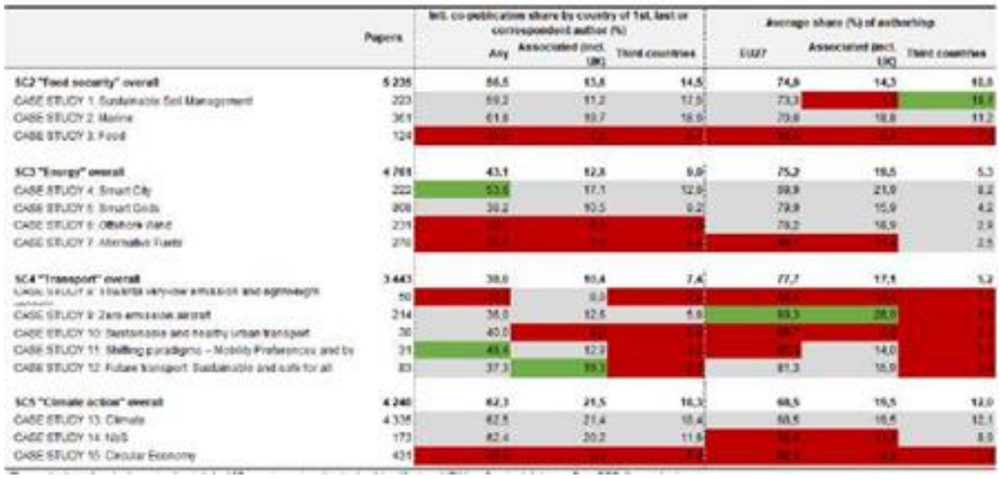
There are still areas to be resolved in order to “roll out” NBS at a European level. For instance, despite having predominantly involved research and higher education institutions, outputs in the form of scientific publications are rather low (37 relevant articles for 38 projects), which, however, fared very well with regard to co-authorship diversity compared to other case studies under Societal Challenge 5. Other output included policy briefs to inform decision-makers, publicly available reports, as well as webinars and e-learning events that were accessible to the different target audiences of a project.

Knowledge sharing was enabled through the dedicated platforms and operating liaison groups set up to enable peer-to-peer exchange partners from the academic or private sectors. These groups were often formed around specific topics of interest or shared challenges and led to the formation of the community of interdisciplinary practices in the NBS field. These involved certain academic disciplines more than others (e.g., urban planning more than architecture).

Transdisciplinary research and the emphasis on co-creation through living lab approaches ensured that also laypersons’ perspectives (e.g., citizens) were taken up, further enriching knowledge co-production with experts and users. Furthermore, the projects co-produced new knowledge in an interdisciplinary way involving natural science, technological and social sciences, yet the connection to policy-making at the regional, urban and national levels is still to be fostered. A systemic, transformative approach, including the transformation of institutions and more governance-related knowledge, as well as related knowledge exchange on best practices and lessons learned, would be helpful for NBS to gain track successfully.

International cooperation and participation is generally regarded as highly valuable by both the policy and research community. Some actions in the portfolio included urban partners outside Europe (e.g., in Colombia, Turkey and Vietnam); computed bibliometric output data available regarding international collaboration in science reflected these efforts as compared to the other SC5 cases and underscored an important knowledge and collaboration pathway.

H2020 Green Transition case studies: Bibliometric Indicators of international collaboration in papers



	Papers	Intl. co-publication share by country of 1st, last or correspondent author (%)			Average share (%) of authorship		
		Any	Associated (incl. UK)	Third countries	EU27	Associated (incl. UK)	Third countries
SC2 "Food security" overall	**5 236**	**56.5**	**13.8**	**14.5**	**74.9**	**14.3**	**10.8**
CASE STUDY 1: Sustainable Soil Management	223	59.2	11.2	17.5	73.3	[illegible]	[illegible]
CASE STUDY 2: Marine	361	61.8	10.7	16.6	70.0	18.8	11.2
CASE STUDY 3: Food	124	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SC3 "Energy" overall	**4 769**	**43.1**	**12.8**	**9.9**	**75.2**	**19.5**	**5.3**
CASE STUDY 4: Smart City	222	53.6	17.1	12.6	69.9	21.9	8.2
CASE STUDY 5: Smart Grids	908	39.2	10.5	8.2	79.9	15.9	4.2
CASE STUDY 6: Offshore Wind	239	[illegible]	[illegible]	[illegible]	78.2	16.9	2.9
CASE STUDY 7: Alternative Fuels	270	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.5
SC4 "Transport" overall	**3 443**	**38.0**	**10.4**	**7.4**	**77.7**	**17.1**	**5.2**
CASE STUDY 8: [illegible]	50	[illegible]	0.0	[illegible]	[illegible]	[illegible]	[illegible]
CASE STUDY 9: Zero emission aircraft	214	38.0	12.6	5.6	69.3	28.0	[illegible]
CASE STUDY 10: Sustainable and healthy urban transport	30	40.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CASE STUDY 11: Shifting paradigms – Mobility Preferences and by	31	48.4	12.9	[illegible]	[illegible]	14.0	[illegible]
CASE STUDY 12: Future transport: Sustainable and safe for all	83	37.3	33.3	[illegible]	81.3	15.9	[illegible]
SC5 "Climate action" overall	**4 240**	**62.3**	**21.5**	**16.3**	**68.5**	**19.5**	**12.0**
CASE STUDY 13: Climate	4 335	62.5	21.4	16.4	68.5	18.5	12.1
CASE STUDY 14: NbS	173	82.4	20.2	11.6	[illegible]	[illegible]	8.9
CASE STUDY 15: Circular Economy	431	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 261. International Collaboration in Papers – excl. JTI, incl. (some) PPP

Source: Science Metrix

14.4.3. Market & Business Pathway

The market & business pathway emphasizes a whole new mindset towards governance as well as business and financing models. According to our interviewees, to this end, a list of commercial and social enterprises active in NBS-related activities has been compiled, yet the Covid-SARS-19 pandemic impacted substantially on further related compilation activities, similar to NBS implementations and EU H2020-funded projects (including extensions). Greater involvement of public and private actors is well reflected in the participation pattern of the projects. However, projects under the Green Deal call – combining pro-growth and ecological sustainability – are still ongoing at the time of writing, and while previous projects focus on the marketability of NBS tools, as well as increased awareness, visibility and implementation of real-world solutions through a focus on pilot and demonstration activities for testing, their effectivity is hard to assess.

To enable inspiration and change mindsets with regard to broad societal and MS governmental NBS acceptance, one informant stressed the importance of creating a common vision, coherent governance and clear legal frameworks within platform projects such as NATURVATION or URBAN GreenUP. Another crucial aspect of such projects could be ambassadors, committed persons who take on the spirit and drive of implementation having the relevant networks and channels to accelerate change.

Several barriers and challenges in the area of market integration and creating new markets have been detected. In particular, NBS as an umbrella term encompasses several subsets of programs and approaches, which have been researched and implemented under different names previously. It is therefore important to foster dissemination and awareness raising while adapting NBS tools and focus areas according to local needs and requirements. Others mentioned that the end of the project was a barrier to market integration, as there are no longer incentives to work on the 'last mile'. To counter this, one expert stressed that projects whose products are close to being ready for the market should be provided with an assessment and potential follow-up funding. Concerning creating new markets, respondents stressed that this goes beyond the impact of such projects. What they can do, however, is to create *collaborative* business models that involve key actors in developing an NBS set. In addition, some interviewees emphasized that the nature of public administration is often difficult to manage, but not to create innovative strategies with the potential to replicate in other contexts. Moreover, it is often difficult for cities to involve companies in developing solutions because of conflicts of interest. While a city is interested in finding the right solution for its specific context, companies often look for business cases with high replication potential and positive economies of scale.

Respondents report that it is often easier to work with city-owned companies, as this circumvents the conflict of interests.

Overall, only 5 SME projects within NBS-related calls provide a rather thin basis for assessing business-driven demands, yet it has been noted in the interviews that “size matters”: only mid to large companies would have the financial means to actually sustain the implementation of NBS and transformative innovations, making additional funding instruments and coherent implementation strategies for SMEs more relevant. A key area for future NBS projects and successful implementation relates to activating sustained private financing (including legal and insurance-related aspects), which needs to be fostered through future Horizon Europe-funded actions.

14.4.4. Technology & Innovation Pathway

The projects in the work programs are inherently innovative and predominantly focused on improving adaptation and resilience, e.g. to droughts and floods, by means of providing integrated NBS toolkits and learning, as well web-bases NBS-related identification tools (Nature4Cities, UNALAB, etc.). This involved the deployment of a portfolio of solutions as part of a new system or their deployment and integration into an existing system and improvements in the services that ecosystems provide. Many actions focused on the urban environment, but MERCES focused on marine ecosystem restoration, while NAIAD looked at insurance-related values to reduce human and economic risks.

Overall, most technology and innovation action focused on some sort of stock-tacking of NBS tools and clustering, as well as transforming them into decision support tools. Demo cases and demonstrators, e.g., in MERCES, showed that “regenerative agriculture, for example, has significant co-benefits, including water storage from reduced ploughing and increasing soil biodiversity and organic matter.”[1]

Moreover, improving the prediction and modelling of hazards and risk through ICT tools for city climate and water resilience has been high on the agenda, involving participatory and collaborative techniques. In addition, with relevant financing framework research and innovation (e.g., DELTARES) and the above-mentioned action in the field of insurance schemes, NBS action under H2020 confirmed the transition to the outlined transition towards NBS focused on adaptation.

14.4.5. Policy & Standards Pathway

NBS build on a long-standing policy trajectory, including the EU Strategy on Adaptation to Climate Change (2013), the EU Green Infrastructure Strategy (2013), the EU Biodiversity Strategy for 2020 (2011), the EU “Blueprint to Safeguard Europe’s Water Resources”, the EU Action Plan on the Sendai Framework for Disaster Risk Reduction and the EU Policy on international ocean governance (2016). Projects developed in the portfolio directly speak to these frameworks.

According to our interviewees, European NBS's ambition largely contributed to setting the pace at the international level in the field, clearly strengthening the global leader’s role in this regard. Examples mentioned were the role of the EU delegation at the UN-HABITAT III conference in Quito in 2016 and the contribution to the New Urban Agenda. What is more, NBS and “flagship” projects, such as NATURVATION, ThinkNature and Nature4Cities, carved out what could be called a distinctively “European approach” to climate adaptation and urban resilience today by putting economy-positive “renaturing urban planning” high up on the agenda.

Yet how to improve the policy framework for NBS at the European level is still very much a work in progress. It is clear now that climate change and biodiversity loss are interdependent and that Green Deal, biodiversity and sustainable development goals can only be achieved if scaling up and speeding up the implementation of technology and society-driven NBS. In this sense, the portfolio helped to create the necessary knowledge and networks for the NBS manifesto, launched at the 2019 Climate Action Summit with the support of more than 70 governments, the private sector, civil society and international organizations. There is nowadays a strong international commitment to NBS, and at the

EU level (reflected by the NBS Contribution Platform, hosted by UN Environment), the European Green Deal recognizes the key role of protection and restoration of ecosystems, including through NBS. Achieving biodiversity and climate objectives will depend on the successful deployment of NBS timely and at scale. Embedding NBS in sustainable urban planning and at the territorial level in regions has been demonstrated to help mainstream NBS.

However, from the research community, there are also important voices alerting for NBS to become merely a new off-setting mechanism, as well as over-claiming them. NBS are location and context-specific and need differential time scales to thrive. In this sense, NBS cannot be seen as a "silver bullet". Accordingly, for NBS to fully unlock their potential for providing progress on both climate change mitigation and adaptation while contributing to other key agendas on biodiversity and human wellbeing, it is key to link agendas, stakeholders, and action into a coherent proposition supported by examples and stories that can help to create an understanding of and demand for NBS for climate amongst a wide range of actors from governments to the finance sector and business.

At a more operational level, standardization of indicators, data and platforms has played a considerable role in Horizon 2020, and the interviews also stressed that attention and funding to these topics should be sustained. For holistic NBS implementation approaches, the requirement of developing standardized platforms and interfaces that enable NBS integration not only on a project basis but also at a system level, dealing with the interfaces of energy and food supply, disaster risk reduction, biodiversity enhancement, mobility and housing could further contribute to the integration of already existing technologies and improve urban and key ecosystem-service planning.

14.5. Conclusion

EQ 4.2. Which internal or external factors (such as access to specific stakeholder groups, change of understanding of 'innovation processes' etc…) have influenced progress or lack of progress of the Framework Programme interventions in this area towards their impact? What could be done to address these in the short and longer term? Are there any factors that are more or less effective than others, and, if so, what lessons can be drawn from this?

The work programmes have established a portfolio of interventions in the NBS field which provided important foundations for progress towards EU policy priorities and objectives related to the green transition.

Each of the pathways identified in this case study has contributed to this portfolio by a) establishing the relevant networks and fostering interdisciplinary collaboration and b) enabling innovative decision support and integrated eco-socio-technical solutions to the challenges associated with a predominantly urban green transition. Taken together, this portfolio provides a valuable basis to be built on by Horizon Europe initiatives such as the Climate Mission or the Partnership Driving Urban Transition (DUT).

Further strengthening the portfolio by developing systemic solutions which target the monitoring, governance, legal, financing and sociocultural conditions in which NBS is locally embedded will be key, as well as finding common denominators and demonstrators for upscaling. While the selective focus on learning and connection platforms with regard to three main ecosystems (urban, coastal and freshwater) in the work programs was valuable, it is important to also develop social or institutional innovations which cannot be based on exchange alone but would require the development of additional FP instruments (and beyond) and suggest structural changes regarding the EC RTD governance and DG collaboration.

EQ. 4.1 What are the main results and (expected) outcomes and impacts from the projects supported in this area? Is the delivery of the projects' results altogether leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe?

According to our interviewed experts, the outcome (as far as available as of now) and impact of projects has been overwhelmingly positive. First, inter and transdisciplinary R&I has been fostered, essential community network and decision support platforms were/are established, and respective databases/tools as well. Projects have effectively rendered proof that NBS have the potential to achieve what they are supposed to do, at least in the urban context and with regard to the participation of public administrations and other governance actors. The thematic transition from NBS towards NBS with a clear adaptation focus has been linked to the Covid-10 pandemic and the impact of climate change in Europe. However, there are several voids to be explored further: the almost complete absence of NBS with regard to rural contexts (especially agriculture and food supply, only occurring in SC3), the enormous focus of NbS project within the core countries (EU13 virtually absent in the projects), but also with regard to research (in particular, nature, life and tech-sciences) on the long-term monitoring of implementation related effects of NBS and the interdependencies across micro-ecosystems of such impact. Overall, while some DG representatives claim to have sufficient knowledge established in H2020 to now move to broad implementation in Horizon Europe, the scientific community is less enthusiastic and asks for more research (on impact and cascade effects) with a duration of at least 5 to 7 years.

E.Q. 4.3: ***To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts?***

Effective mechanisms for communication and dissemination support the capitalization on the investment made by the work programmes. This case study gathered evidence on a number of actions, from project to program level, for improving communication & dissemination measures for impact. First, at the project level, the learning and capacity-building of project stakeholders helped to improve the effectiveness of their individual project communication activities beyond traditional scientific channels and audiences. According to Science Metrix bibliometric data, open access publishing is at a 79.5% rate, which is close to the climate case within SC5 (84.1%). Regarding concrete channels within the three SC5 cases, outreach via news and Facebook has been more effective than Twitter and generally fared better than in the Circular Economy case. Second, at the program level, communication and dissemination measures were particularly effective when they addressed the specific needs of a particular stakeholder group. However, to do so, sustained project monitoring at the program level is key and cannot always be ensured. Fostering twinning and leader/follower pairing could provide effective mechanisms for matching stakeholders with shared interest, shared challenges or challenges owners with solution providers. On this basis, communication & dissemination measures were more targeted and thus effective in supporting the mutual information, learning and decision support availability of project results. Fourth, pursuing strategic partnerships with multiplier organisations that have established thematic networks at the international level (e.g., IUCN, UNEP, IPBES, Sendai) was beneficial to improve outreach. Such partnerships are also critical with regard to national R&I stakeholders, who are most effective in communicating through appropriate national channels, further improving outreach.

EQ 4.5. To what extent has international cooperation and, more specifically, association of third countries to the EU Framework Programme made a difference in achieving the environment related objectives of the Framework Programme?

Overall, with regard to SC5, international cooperation with third countries should have been an important facet in the relevant H2020 work programmes and underlined the EU leadership role in tackling global challenges associated with the triple nature, climate and pollution crises. Funded research underscores the need for continuously fostered cooperation with third countries in the field of NBS and particularly NBS focused on adaptation; important to broaden research perspectives and to mutually learn from new approaches and solutions to green transition challenges in the climate adaptation and resilience field linked to NBS. This was confirmed across all interviews but is also reflected by 21 third-country project participations. Moreover, investments in international cooperation can expose partners to the demands of international markets and provide first market entry points to them at a larger scale. In this sense, international cooperation under H2020 has received good attention (with some exceptions, particularly in Eastern Europe), explicable perhaps by first developing and testing a proper NBS approach by leading consortia in the EU.

EQ 5.1. What is the EU added value of the Framework Programme in this area? What would have happened if the Framework Programme had not existed?
With regards to EU added value, the work programmes have created highly ambitious EU flagship initiatives which have demonstrated how overarching policy objectives can be operationalized and turned into concrete decision support tools. The effectiveness of these interventions, and thus EU added value, can be further leveraged by improving the alignment with national and sub-national strategies and activities in terms of finding synergies, complementarities, or multiplier effects at national, regional or city levels in order to draw in additional stakeholders and tap into private and public sector funding streams.

However, an enormous discrepancy in EU added value between the EU 15 and EU 13 member states is imminent, which is partly rooted in historically grown structural differences of the national R&I systems between both groups, but in the field of NBS, particularly striking, related to diverging policy priorities, especially since 2018. The participation of the EU13 Member States is very low (they were involved in 10.1% of the projects), and accordingly, the EC contribution is also very low at 8.1% of the total contribution (in comparison, EU14 countries receive 68.1% of the total contribution with a funding of 741 million Euro). This innovation gap limits the potential to achieve EU-wide policy priorities associated with a green transition based on NBS actions.

14.6. Annexes

Table 118. Key metadata – CS14 Nature-based Solutions.

CS 14	**Nature-based Solutions**
Evaluation Question addressed*	EQ 4.2.; 4.3; 4.4.; 4.5.; 5.1.
Area	Climate
Programme parts	WP 2014/2015 (food and blue growth) WP 2016/2017 (Biodiversity, Industry 2020 and Food, Blue Growth) WP 2018/2020 (Climate action, environment, resource efficiency and raw materials)
Scope	11 Horizon 2020 calls & relevant JPI Calls (ERA NETS) Time horizon covered: 2014 – 2020. Number and type of instruments analysed: 14 RIAs, 5 CSAs, 19 IAs. Number of projects analysed: 38
Key data sources	H2020 Work Programs & relevant call text JPI UE, JPI Climate, JPI Oceans call texts Project data from CORDIS & CORDA 9 interviews Strategic Policy Documents
Relevant policies	EU Strategy on Adaptation to climate change (2013) EU Green Infrastructure Strategy (2013) EU Biodiversity Strategy for 2020 (2011) EU “Blueprint to Safeguard Europe’s Water Resources” EU Action Plan on the Sendai Framework for Disaster Risk Reduction EU Policy on international ocean governance (2016).

	New Urban Agenda Sustainable Development Goals European Urban Agenda European Green Deal
CS 14	**Nature-based Solutions**
	EU Urban Initiative

Table 119. Project information (21 project selection).

CLEARING HOUSE	httpsV/cordis europa. eu/ project/id/821242	http://clearmghouseproject.eu/	SC5-13- 2018-2019	Research and Innovation
CLEVER Cities	https://cordis.europa.eu/ project/id/77ö604	https://clevercities.eu/	ECC-02- 2016-2017	Innovation action
Connecting Nature	https://conlis.europa.eu/ project/id/730222	https://connectingnature. eu/	SCG-02- 2016-2017	Innovation action
DRYvER	https://cordis.europa.eu/ project/id/869226	https://www-diyver.eii/results	LC-CLA-06- 2019	Research and Innovation action
EdiCi ŁNet	https://cordis.europa.eu/ project/id/776665	https://www.edicitnet.com/ mediabbrary/deliverables/	SCC-02- 2016-2017	Innovation action
EuPOLIS	https://cordis.europa.cu/ project/id/869448	http://eupolis-prpject.eu/	SC5-14-2019	Innovation action
FutureMARES	httpsf//cordis europa. eu/ project/id/869300	https://www.fii Euremares.eu/	LC-CLA-06- 2019	Research and Innovation
GrowGreen	https://cordis.europa.eu/ project/id/7302B3	http://growgreenproject.eu/	SCG-02- 2016-2017	Innovation action
NAIAD	https://cordis.europa.eu/ project/id/730497	http://naiad2020.eu/	SC5-09-2016	Research and Innovation action
Nature4Cities	https://cordis.europa.eu/ project/id/730468	https://www.na Eure4cities. eu/	SCC-03- 2016	Research and Innovation action
NATURVATION	https://cordis.europa.cu/ project/id/730243	https://www.na turva tion. eu/	SCC-03- 2016	Research and Innovation action
OPERANDŬM	https://cordis.europa.eu/ project/id/77öB48	https://wivw.operaiiduHi-pEoject.eu/	SC5-0B-2017	Innovation action
PHUSICOS	https: //cordis.europa.eu/ project/iil/77ö6BI	https://phusicos.eu/	SC5-08-2017	Innovation action
proGireg	https://cordis.europa.eu/ project/id/776528	https://progireg.eu/	SCG-02- 2016-2017	Innovation action
RECONECT	https://cordis.europa.cu/ project/id/776866	http://www.reconect.eu/	SC5-08-2017	Innovation action
REGREEN	https://cordis.europa.cu/ project/id/821016	https://wivw. re gr cec.-pr oi cct euf	SC5-13- 2018-2019	Research and Innovation action
RENATURE	https://cordis.europa.eu/ project/id/809988	http://renature-project.eu/	*	Coordination and support action
ThinkNature	https://cordis.europa.cu/ project/id/730338	https://wivw.thinli-nature.eu/	SC5-10-2016	Coordination and support action
UNalab	https: //cordis.europa.eu/ project/id/730052	https://unalab.eu/en	SCC-02- 2016-2017	Innovation action
Urban GreenUP	https://cordis.europa.eu/ project/id/730426	https://wivw.urbangreenup.eu/	SCG-02- 2016-2017	Innovation action
URBiNAT	https://cordis.europa.cu/ project/id/77ö7B3	https://urbinat eu/	SCC-02- 2016-201	Innovation action

Table 120. Interviewed Experts.

Name	Organisation	Justification
Julie Delcroix	DG R&I	NBS Expert
Gilles Doignon	DG R&I	NBS Expert
Prof. Dr. Raúl Sanchez	CARTIF	Expert on alternative, hybrid-electric propulsion systems
Name	**Organisation**	**Justification**

Elisa Grafulla Garrido	EU BAUHAUS, Main author expert report	PO
Sofie Vandewoestijne	European Research Executive Agency Unit REA.B3 – Biodiversity, Circular Economy and Environment	Former RTD PO
Paul Mahony	OPPLA	Responsible for implementation of Framework Programme and project selection procedure
Wouter Vanneuville	Expert European Climate Adaptation Platform/CLIMATE-ADAPT	Overview of project's implementation, result and (potential) impact
Karin Zaunberger	PO, DG ENVIRONMENT Biodiversity Unit	Relevant NBS expert and report co-author
Franz Immler	CINEA	HoS

[1] CORDIS Results Pack on nature-based solutions, 2020.

[1] See: https://jpi-urbaneurope.eu/calls/intro/

[1] Mario J. Al Sayah, Pierre-Antoine Versini, and Daniel Schertzer, "H2020 Projects and EU Research Needs for Nature-Based Adaptation Solutions," Urban Climate 44 (July 2022): 101229, https://doi.org/10.1016/j.uclim.2022.101229.

[1] See: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-intro_en.pdf

[2] See: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-intro_en.pdf

[1] Nature-Based Solutions in Europe Policy, Knowledge and Practice for Climate Change Adaptation and Disaster Risk Reduction., 39.

[2] European Commission. Directorate General for Research and Innovation., The Vital Role of Nature-Based Solutions in a Nature-Positive Economy. (LU: Publications Office, 2022), p.12, https://data.europa.eu/doi/10.2777/307761.

[1] UNEP/EA.5/L.23/Rev.1

[2] European Environment Agency., Nature-Based Solutions in Europe Policy, Knowledge and Practice for Climate Change Adaptation and Disaster Risk Reduction. (LU: Publications Office, 2021), https://data.europa.eu/doi/10.2800/919315.

[3] https://portals.iucn.org/library/node/49070

[1] See: https://unric.org/en/sdg-11/, page visited on 22.04.2022

[2] Faivre et al., 2017.

[1] Nicolas Faivre et al., "Nature-Based Solutions in the EU: Innovating with Nature to Address Social, Economic and Environmental Challenges," Environmental Research 159 (November 2017): 509–18, https://doi.org/10.1016/j.envres.2017.08.032.

15. Case study 15: A sustainable, resource efficient circular economy - innovation in support of sustainable supply and use of raw materials

15.1. Summary

This case study focuses on Horizon 2020 funding in the Circular Economy and innovation support for the production of raw materials. This topic has increased in relevance over the course of the H2020 Framework Programme. For the analysis of this case study, we conducted 5 interviews with various stakeholders and analysed 102 projects under 5 calls and 34 Topic IDs tackling Societal Challenge Area 5, with high relevance to the case study.

It has been found that Horizon 2020 ensured that, first, important steps towards more Circular Economy approaches were set. In the earlier stages, Circular Economy was still framed as a waste-related challenge, while in later years, a more holistic, more policy-coherent view of the Circular Economy started to emerge in the Horizon 2020 calls. The results of the Circular Economy Horizon 2020 projects are generally positive: they have led to more insights into Circular Economy opportunities on a material level, city level and value-chain level. At the material level, new insights have been discovered on the recyclability of materials. At a city level, Horizon 2020 projects supported the exchange of best practices. At a value-chain level, more collaboration for circular approaches has been established within EU-wide value chains.

Factors for this success were the relatively high involvement of the private sector and the relatively high share of Collaboration and Support Actions. A key area of improvement for the next Framework Programmes concerns improved communication between DG RTD and DG ENV: this would be crucial to increase the relevance and coherence of the next calls with existing and coming Circular Economy policies. Another area of improvement would be the extent to which policymakers in DG RTD and other DGs are updated on the results of the Horizon 2020 projects, which could be useful to feed into their policies to make those more coherent with new, circular business models.

15.2. Introduction and overview

15.2.1. Objectives of the case study

This case study identifies and analyses relevant actions related to Circular Economy in Horizon 2020. It provides an assessment of the implementation of the Framework Programme and shows how the results and outcomes of the funded projects contribute to the overarching goals of the Horizon 2020 programme conception and address the question of whether Horizon 2020 provided a strong basis for developing and progressing the Circular Economy within the EU. Against this background, the main objective of this case study is to analyse to which extent Horizon 2020 actions enabled an effective approach for creating a Circular Economy that can be further scaled up in Horizon Europe.

The reason for the selection of the Circular Economy as a case study is that it is an increasingly important area of European focus area within the Green Transition. The launch of the Circular Economy Action Plan is illustrative of this increased importance, as it is one of the pillars of the EU Green Deal. Circular Economy approaches are seen as solutions to achieving a sustainable way of living and an environmentally friendly economic model. It is different to the currently dominant linear economic model approach in the sense that it comprises life cycle thinking, where waste is seen as a resource and input needs are minimized1. It is an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes.2

15.2.2. Scope of the case study

The case study focuses on Horizon 2020 funding in the Circular Economy. Circular Economy as a concept is relatively new. Especially at the start of H2020, in 2014, the concept was still emerging as a topic, while over the past 8 years, it has become more established. There has been quite some discussion in academic circles on what exactly the Circular Economy does and does not entail.3 Considering the complexity of this policy area and in order to narrow down the scope of this case study, we will prioritise the technical cycle of the Circular Economy "Butterfly Diagram"4 (Figure 282), leaving out the biological cycle (left side of the diagram) as well as water-related initiatives (this will be covered as part of other case studies). Following this approach, the case study focus will be primarily on products, their lifecycle and related business models.

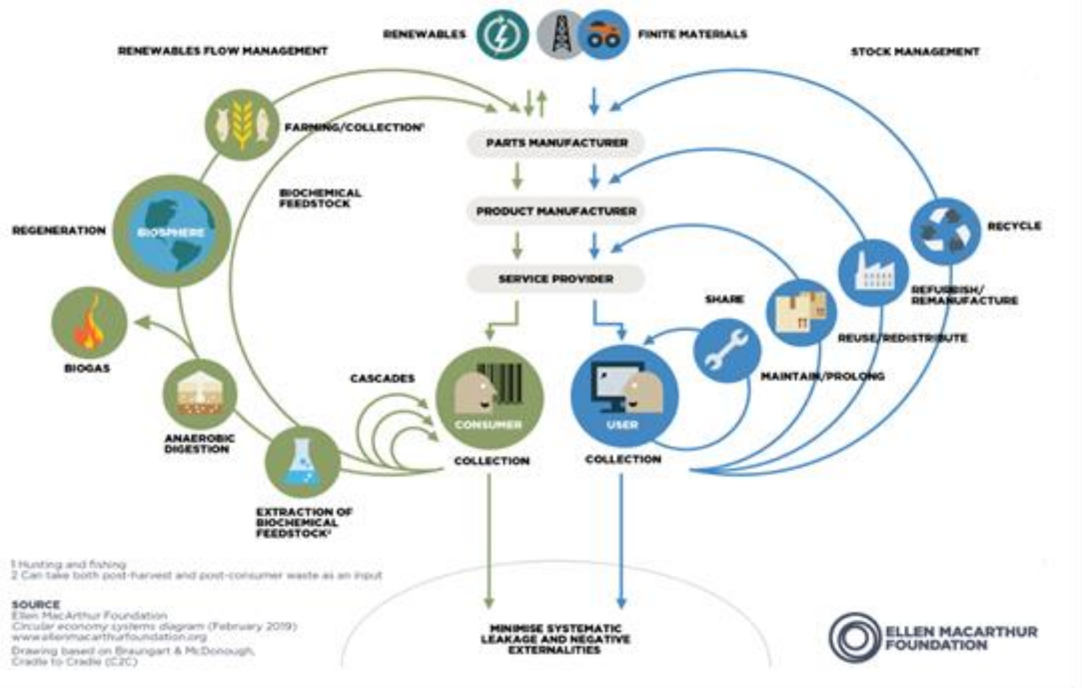


Figure 262 The butterfly diagram: visualising the Circular Economy.

Source: Ellen MacArthur Foundation (2019)

A screening of the H2020 project portfolio revealed 102 projects under 5 calls and 34 Topic IDs with high relevance to the case study: Circular Economy and innovation support for the production of raw materials. These projects and actions tackle Societal Challenge Area 5. For an overview of the calls and the number of projects under the calls, please see Appendix B.

15.2.3. Methodology for the case study

The analysis comprised 5 Horizon 2020 calls. The time horizon covered with the analysis is 2014-2020. The number and types of instruments analysed are 32 Research and Innovation Actions (RIAs), 28 Collaboration Coordination and Support Actions (CSAs), and 39 Innovation Actions (IAs). An overview is provided in Appendix B of this case study.

The analytical approach commenced with a thorough analysis of work programmes, relevant call texts, and strategic documents related to the Circular Economy. Also, academic sources relating to Horizon 2020 and its impact on Circular Economy in the EU6 have been consulted, particularly sources on innovation in support of sustainable supply and use of raw materials and other sources communicating H2020 results. We then identified relevant project actions in Horizon 2020 based on a keyword search of topics in the work programme. For the identified projects, relevant data from Cordis/Corda have been compiled and analysed and complemented by additional sources like project websites.

In addition to the project data analysis, we performed 5 interviews with relevant stakeholders. The interviews comprised representatives of thematic experts involved in the European strategic process, project beneficiaries and Circular Economy experts. Please see Appendix A for an overview of the interviewees. The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus.

For synthesizing the analysis, we triangulated and analysed the findings in relation to the evaluation questions.

15.3. Synthesis of evidence

15.3.1. Strategic policy priorities related to Circular Economy

Circular Economy is defined by the European Commission as an economic system which aims to maintain the value of products, materials, and resources for as long as possible by returning them to the product cycle at the end of their use. This efficient use and reuse of resources results in less raw materials being extracted and minimises the generation of waste.

Establishing the sustainable use of raw materials within the Circular Economy has been identified as a key part of the European Green Deal, as it aims to transform the Union into a modern, resource-efficient, and competitive economy. The Green Deal aims to utilise research and innovation to transform practices in eight domains, one of which is directly relevant to the Circular Economy. The European Union currently produces more than 2.5 billion tonnes of waste every year. To combat this, the Circular Economy Action Plan (COM/2020/98) was proposed in support of the Green Deal in 2020. The plan includes motions for sustainable product design, waste reduction, and consumer empowerment through a system such as the right to repair.

It is important for this evaluation to consider the changes and transition that this policy area has gone through in the last decade (2014-2020), in which Circular Economy became an independent policy area separate from waste management. This is reflected in the recent policies, initiatives, and programmes. In 2014, when the topic was put on the agenda of the first Horizon 2020 Work Programme, there was no clear concept of Circular Economy yet, as confirmed by an interviewee. Only at the very end of the Horizon 2020 2018-2020 Work programme Circular Economy became a clear concept of importance. Still, the concept is rather fragmented and undefined even in the later calls – within the Horizon 2020 Work Programmes, there was no bigger picture for Circular Economy calls yet. Also, the topics related to Circular Economy that received attention within the Work Programmes changed over time. Earlier, the topics were mostly limited to waste and construction materials. Later, applications of Circular Economy concepts in other fields, such as agriculture, became more of a focus. Communication between DG RTD and DG ENV was increased concerning calls relevant to Circular Economy. This makes sense, given the development of the Circular Economy as a concept over the years of the Horizon 2020 Programme.

Circular Economy became more defined due to multiple developments happening in parallel: the formulation of the Sustainable Development Goals (SDGs), the launch of the EU Green Deal and the EU Circular Economy Action Plan. In 2015, the SDGs were formulated by the United Nations (UN). In the years after that, the SDGs became increasingly adopted by policymakers all over the world, also in Europe. Circular Economy is linked to various SDGs, but most explicitly to SDG 12: Ensure Sustainable Consumption and Production Practices8. In 2019, Executive Vice-President Frans Timmermans presented the EU Green Deal, which provides “a roadmap with actions to boost the efficient use of resources by moving to a clean, Circular Economy and stop climate change”9. This quote shows the importance of the Circular Economy within the context of the Green Deal. In 2020, the Circular Economy Action Plan was presented as part of the Green Deal10. In 2021, additional measures were suggested to achieve a carbon-neutral, environmentally sustainable, toxic-free and fully Circular Economy by 2050 (alongside binding targets for 2030 regarding materials use and consumption).11 These developments show the gradual development of the Circular Economy as a priority within EU policy, mainly after the Horizon 2020 FP calls were published.

15.3.2. Horizon 2020 programming related to Circular Economy

15.3.2.1. Horizon 2020 Work Programmes related to Circular Economy

Within Work Programme 2014-2015, waste calls had a clear focus because they were based on the Seventh Framework Programme project VOICES. This project defined six thematic priority areas through a participatory approach involving science, technology, civil society organisations and policy experts. These areas are as follows: ‘economic instruments'; 'education and communication'; 'modelling business and consumer behaviour'; 'policy'; 'product /production design'; and 'waste treatment /management'. The specific activities of this call were based on the six thematic areas. The objectives and the goals were also clearly defined and took on a systemic view. The call attempted to address the challenges by: 1. Addressing the gaps in the knowledge base, 2. Identifying the policies, methods and tools needed to tackle the challenge, and 3. Supporting innovators and businesses (SMEs particularly). The call focused on a broad spectrum of activities as well as stakeholders. Cooperation and bringing together stakeholders (including citizens) were part of many of the calls. It is clear that SMEs should be one of the main recipients of the benefits of the call. Other topics within the overall H2020 Work Package also contributed to the objectives of this call. The activities of the call were in line with other EU Strategies, Partnerships, Directives or Roadmaps.

The Work Programme 2014-2015 call on Growing a Low Carbon Resource Efficient Economy with a Sustainable Supply of Raw Materials, also considered a multidisciplinary approach to achieving the objectives. It aimed to bring together and better coordinate R&I on this topic in the EU and internationally. It focused on supporting businesses and making the public sector make use of the outcomes. This is a more practical call as compared to the Waste call. It is also in line with the Strategic Implementation Plan of the European Innovation Partnership (EIP) on Raw Materials.

Work Programme 2016-2017 was, compared to the previous Work Programme, more defined. Therefore, the calls were relatively more specific. The Programme was in line with other EU Circular Economy-related policies, plans, and strategies, as well as with other communities and the SDGs. In addition to that, the call was complementary to another call, namely: 'Industry 2020 in the Circular Economy'. The Work Programme clearly considered the international aspects and actively encouraged international cooperation for some of the calls. The types of calls included a wide range of projects, from promoting new solutions to developing pilots, supporting policymaking, and facilitating international discussions. Because the calls were more clearly defined, it was easier to point out the requirements and anticipated impacts. However, due to the more specialised topics of the calls, the calls also became more detailed and elaborate.

Work Programme 2018-2020 was specifically focused on the Sustainable Development Goals. It was also designed to contribute to implementing the Circular Economy Action Plan and other key high-level EU priorities. It aimed to make use of a multi-disciplinary approach. Just like the other two Work Programmes, it aimed to facilitate bringing together stakeholders. The call identified the links to other complementary H2020 activities.

We notice that over time the focus shifted from clearly having a goal of supporting SMEs to also considering other actors, including policymakers, the global community (in the respective topic) and industry. SMEs are still important actors in the calls.

The Work Programmes are coherent with other general international or EU priorities, strategies, directives or roadmaps. Especially after the introduction of the SDGs, it is evident which goals the calls contribute to.

15.3.2.2. Summary of strategic policy priorities

From the H2020 Work Programmes (WPs) and Circular Economy-related project descriptions, a number of key strategic policy priorities become apparent, see Figure 283.

Coordination & collaboration	Circular business models	Material recovering & recycling	Circular economy-based policies
• Integrating production, use and end-of-life phases in value chains • Increasing collaboration between sectors for CE models	• Finding economically viable circular business models • Shift to service business models	• Critical materials for energy transition • Plastics • Metal and mineral mining and recycling	• Integrating policies relevant to different sectors

Figure 263 Summary of strategic policy priorities apparent from H2020 WP.
Source: Technopolis Group, 2022, based on H2020 WP and Circular Economy-related project descriptions

The coordination and collaboration strategic priority focuses mostly on getting stakeholders from across value chains to collaborate. This is necessary, as coordination and collaboration were less needed in a linear system. But in a circular system, the various actors need to integrate their material streams: the output of one needs to be used as the input for the next actor. Also, unusual suspects need to collaborate from various sectors. An example of a project that shows these strategic policy priorities are ReCiPSS (Resource-efficient Circular Product-Service Systems, where success factors for circular manufacturing systems in the automotive industry are researched. Another example is the PHOTORAMA project (PHOtovoltaic waste management and advanced Technologies for recovery and recycling of secondary RAw MAterials from end-of-life modules), which has the objective of drawing up a profitable and sustainable circular value chain for a carbon-neutral PV industry.

Secondly, as noted above, economically viable circular business models for private organisations have increasingly become an area of attention. Circular Economy was in WP2014-2015, still seen as primarily a waste-related problem. In the later calls, a more holistic approach to Circular Economy is emerging, one that focuses on circular business models for value chains. An example project is a project CarE-Service (Circular Economy Business Models for innovative hybrid and electric mobility through advanced reuse and remanufacturing technologies and services), which demonstrates a service- and non-ownership-based business model for electric vehicle sharing. Another example is CINDERELA (New Circular Economy Business Model for More Sustainable Urban Construction), which aims to develop a Circular Economy Business Model for the use of secondary raw materials in urban areas with the use of an ICT platform.

A third focus area is research on how to recover and recycle materials. Specifically, there are many projects related to plastic recycling, critical material recovery from waste and turning these materials into a valuable input for new materials, for example, for the energy transition. An example project is NEMO (Near-zero-waste recycling of low-grade sulphidic mining waste for critical metal, mineral and construction raw-material production in a Circular Economy), which focuses on transforming mine drainage problems into resource recovery opportunities. Another example project is the Sol-Rec2 project, which has the objective to research innovative digital watermarks and green solvents for the recovery and recycling of multi-layer materials.

Finally, Circular Economy-based policies and policy approaches focusing on the consequences of Circular Economy are gaining attention in the H2020 FP and its projects. An example of this is the focus of the JUST2CE project: a just transition to the Circular Economy, as the project claims that although there is an increase in the implementation of CE approaches, there is a gap in terms of research into the various implications of the CE paradigm. Another example is the MIN-GUIDE project, aiming to produce Minerals Policy Guidance for Europe.

15.3.3. Project portfolio characteristics

15.3.3.1. Horizon 2020 project portfolio

The portfolio of projects for this case study comprises 99 projects. The next sections break the portfolio up into various categories: participation by stakeholder types, by type of instruments and by country.

15.3.3.2. Participation by stakeholder types in Circular Economy-related H2020 projects

The sum of EC's net contribution is EUR 575 Mio, of which 42% has been allocated to private companies, 27% to Research Organisations, 20% to Higher or Secondary Education Establishments, 4% to Public Bodies, and 7% to Other types of organisations, see Table 2.

Table 121. Types of organisations in H2020 projects related to Case Study Circular Economy.

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part.
		Nb	Share (%)	EUR (1000)	Share (%)	(EUR 1000)
HES	86	278	14%	115 993	20%	417,2
OTH	71	265	13%	39 151	7%	147,7
PRC	96	918	46%	243 933	42%	265,7
PUB	42	143	7%	20 436	4%	142,9
REC	97	398	20%	155 932	27%	391,8
Total (All types)	**99**	**2002**	**100%**	**575 445**	**100%**	**287,4**

HES: Higher or Secondary Education Establishments; PUB: Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments); REC: Research Org.

Source: Science Metrix, 2022. Based on project data from eCorda.

Compared with the average for Societal Challenge 5 Climate Action (SC5) fields (30%), the funding for private organisations is high (42%), indicating a high relevance for the private sector of this area compared to other Climate action areas. Compared to the average for SC2-5 (47%), however, the share of funding for private organisations is slightly lower. Compared with all other Green Transition areas considered in this study (SC2 to SC5), the portfolio of Circular Economy projects has a slightly higher share of funding for research organisations (27% compared to 24% overall), while this is slightly lower than the average for SC5 Climate Action (30%). Higher Education and Secondary Education Institutions receive less funding related to Circular Economy compared to the average of SC5 Climate Action projects (26%), but similar share of the funding as the average for all Societal Challenges SC2-5 (19%). Funding for the other types of stakeholders is more similar to the patterns also visible in SC5 as well as the average for SC2-5: this is true for Public Bodies (the average for SC5 is 8% and for SC2-5 is 5%) and for Other types (average for SC5 is 7% and for SC2-5 is 5%).

15.3.3.3. *Participation by type of instruments and type of stakeholder organisation in Circular Economy-related H2020 projects*

With 30% of funding allocated to Coordination and Support Actions (CSAs), the Circular Economy case study portfolio is characterised by a high degree of actions focused on networking, standardisation and communication, see Figure 284. The average for the aggregated Green Transition project portfolio is a lot lower at 7.4%. In contrast, Research and Innovation Actions (RIAs) are less present in the Circular Economy portfolio than on average in the Green Transition portfolio (27% compared to 42%). The same is true for Innovation Actions (IAs), although to a lesser extent (43% compared to 47%). This shows that the Circular Economy portfolio is characterised by a lower degree of new knowledge production and basic research. Also, the Circular Economy portfolio is slightly less application-oriented than the aggregate Green Transition portfolio.

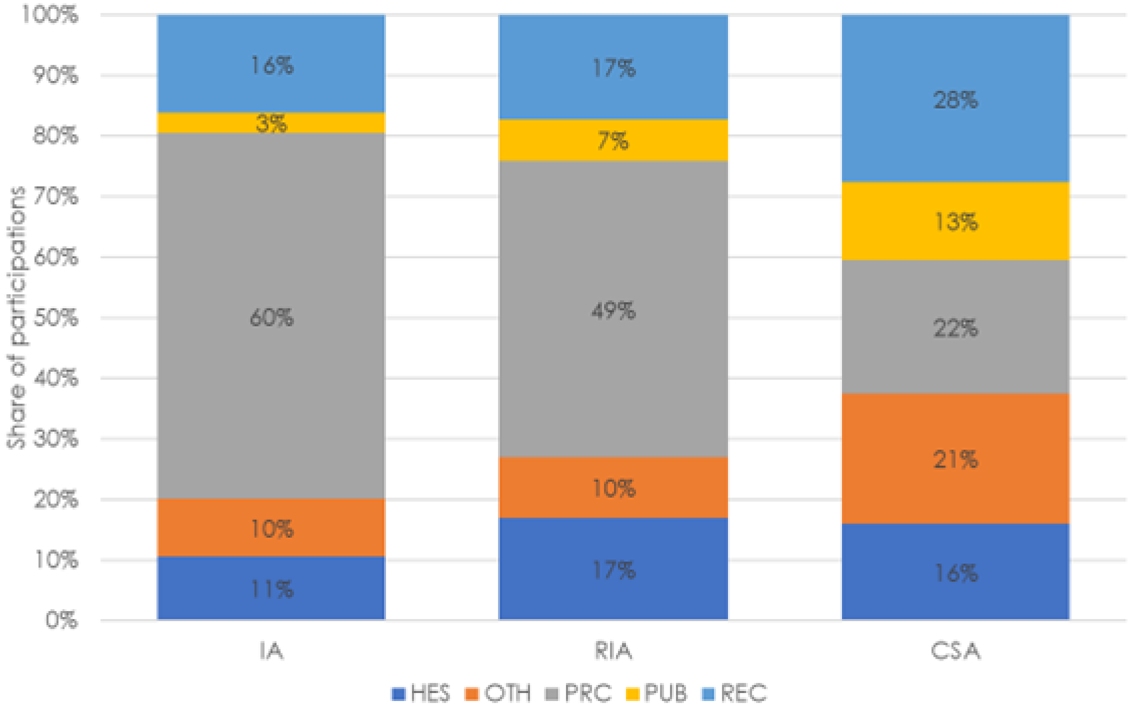


Figure 264 Share (%) of participations by type of stakeholder organisation and type of actions/instruments. IA = Innovation Action; RIA = Research and Innovation Action; CSA = Coordination and Support Action. HES = Higher or Secondary Education Establishments; PUB.

Source: Science Metrix, 2022, based on eCorda data

15.3.3.4. *Participation by countries in Circular Economy-related H2020 projects*

Geographically, the eCorda statistics show that H2020 opened up the participation of especially associated countries and, to a lesser extent, third countries. Associated countries (excluding the UK) participated in 50 out of 99 projects, and Third countries in 25 out of 99. However, in terms of funding, these groups together only receive 7.9% of the total funding. The largest gap in terms of participation in relation to EC contribution is observed for the EU-13 countries, which participated in 60 projects (60%) but received only 5% of the total funding budget. This is a pattern that is consistent with all projects in the Green Transition portfolio (SC2-5). The H2020-EU27, and in particular the EU-2014, are slightly more represented in the Circular Economy-related projects.

Table 122. Groups of countries' (of supported organisations) participation in projects of the case study Circular Economy.

Group of country	Number of projects	Participations		EC contribution		EC Contr. per part.	Number of countries
		Nb	Share (%)	EUR (1,000)	Share (%)	(EUR 1,000)	
H2020-EU27	99	1 724	86,1%	494 433	85,9%	286,8	27
EU-14	*99*	*1 533*	*76,6%*	*465 467*	*80,9%*	*303,6*	*14*
EU-13	*60*	*191*	*9,5%*	*28 966*	*5,0%*	*151,7*	*13*
H2020-associated (exclude UK)	50	114	5,7%	37 301	6,5%	327,2	11
United Kingdom	52	104	5,2%	35 503	6,2%	341,4	1
Third Countries	25	60	3,0%	8 208	1,4%	136,8	20
All-countries	**99**	**2 002**	**100,0%**	**575 445**	**100,0%**	**287,4**	**59**

Source: Science Metrix, 2022, based on eCorda data

The most active countries in Horizon 2020 projects related to Circular Economy are Spain and Germany, which are respectively participating in 75 and 77 out of 99 projects, and get 15% and 13% of the total EC funding, see Table 4. Also, Spain contributes most of the participants with 15%, while Germany is the second provider of participants with 9.7%. Germany also receives the highest EC contribution per participant, with €387k per participant. Within Germany, Fraunhofer Gesellschaft is the most active participant, participating in 20 projects. In Spain, this is the Fundacion Tecnalia Research & Innovation. Other active countries are France, Belgium, and Italy, which are active in 59 to 69 projects each, each receiving 8 to 10% of the EC funding and contributing 7 to 10% of the participants. The UK, the Netherlands, Sweden and Finland follow by participating in 42-52 projects, delivering 4.4-5.2% of the participants and receiving 5-6% of the EC funding. In these countries, the most active participants are VTT Technical Research Centre of Finland (Teknologian Tutkimuskeskus VTT OY), the French geological survey (BRGM, Bureau de Recherches géologiques et Minières), and Delft University of Technology in the Netherlands.

On the downside, a low rate of participation rate of EU-13 indicates a certain level of exclusiveness regarding these countries. This could have negative consequences for the utilisation of the full transformation potential to the Circular Economy across Europe.

Table 123. Top countries (of supported organisations) in projects of the case study Circular Economy.

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Order
		Nb	Share (%)	EUR (1,000)	Share (%)		
Germany	77	194	9,7%	75 018	13%	386,7	1
Spain	75	300	15,0%	88 106	15%	293,7	2
France	69	144	7,2%	43 335	8%	300,9	3
Belgium	67	192	9,6%	60 014	10%	312,6	4
Italy	59	184	9,2%	45 880	8%	249,3	5
United Kingdom	52	104	5,2%	35 503	6%	341,4	6
Netherlands	50	117	5,8%	36 071	6%	308,3	7
Sweden	42	89	4,4%	34 193	6%	384,2	8
Finland	42	90	4,5%	29 965	5%	332,9	9
Austria	37	68	3,4%	17 508	3%	257,5	10
Greece	31	52	2,6%	15 731	3%	302,5	11
Portugal	30	55	2,7%	8 450	1%	153,6	12
Poland	28	38	1,9%	5 636	1%	148,3	13
Switzerland	22	30	1,5%	4 789	1%	159,6	14
Romania	19	32	1,6%	3 251	1%	101,6	15
Slovenia	19	39	1,9%	9 727	2%	249,4	16
Norway	19	40	2,0%	23 193	4%	579,8	17

Source: Science Metrix, 2022, based on eCorda data

Also, when considering the participation between countries (of supported organisations), the EU-14 countries are more active than other countries, see Figure 2. Most of the collaborations in Circular Economy-related H2020 projects took place between Spain (participated in 15% of the projects and received 13% of the EC contribution), Germany (9.7% participation, 13% EC contribution), France (resp. 7.2%, 8%), Italy (resp. 9.2%, 8%), Finland (resp. 4.5%, 5%), Sweden (resp. 4.4% and 6%) and Belgium (9.6% and 10%). The EU-14 countries, on average, participate more often in CE-related H2020 projects than EU-13 countries. This confirms that the core EU-14 countries collaborate more intensively among themselves. The only exception is Luxembourg, which is less present in the CE-related H2020 projects than the other EU-14 countries. However, given its relatively small size as a country, this can also be explained by the lower absolute numbers of Luxembourgian researchers. From the EU-13 countries group, Slovenia, Poland, and Romania are the most linked with the core EU-14 countries.

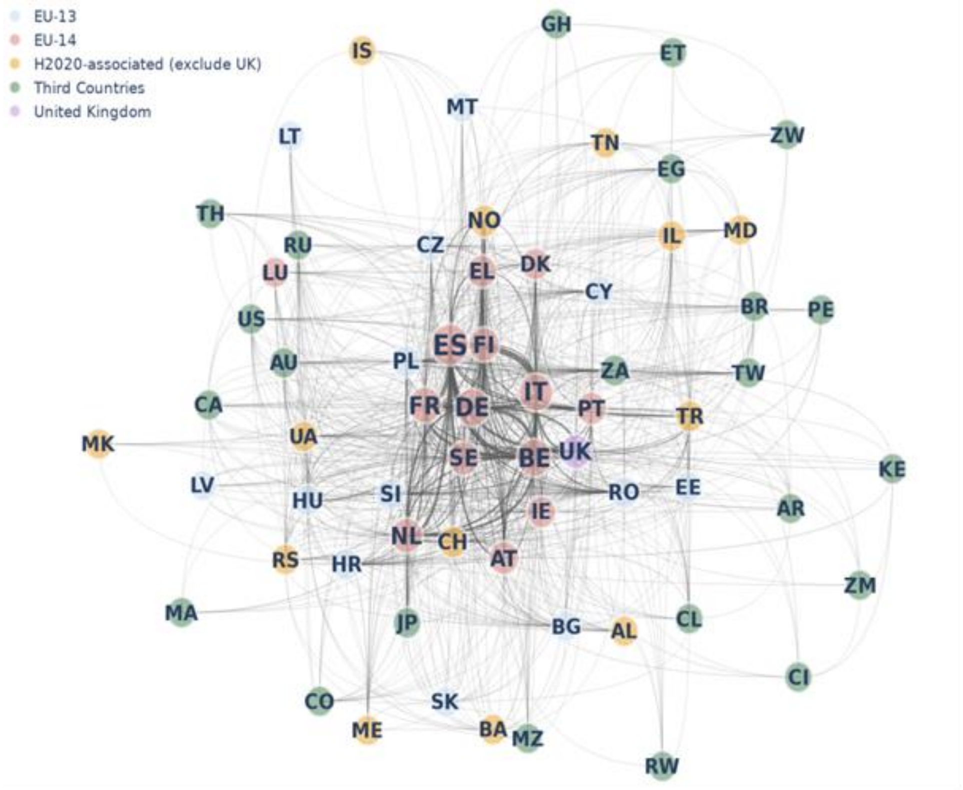


Figure 265 Network of participating countries (of supported organisations) in projects in the Case Study "Circular Economy".

Source: Science Metrix, 2022. Based on project data from eCorda.

15.4. Results of the Horizon 2020 funding activities: pathways to impact

Regarding the **Coordination & Collaboration pathway**, the projects have been successful in bringing stakeholders together that are on different sides of the value chain, thus ensuring more collaboration for Circular Economy. This is important, according to interviews and research papers, as Circular Economy is a topic that is largely about system change. Also, they have supported the coordination between various actors within a value chain, making it easier or possible to make agreements on how to increase the recyclability of products. This is visible from the eCorda analysis – since the CE projects have a higher share of the private sector involved than average. It is also confirmed by several interviewees. From the eCorda analysis, it also becomes clear that collaboration is more intense between within-EU(14) countries. This could be because these countries are most connected economically, so value chains are more concentrated in these countries. An observation in the literature is that third-sector organisations such as NGOs, social enterprises and community-based initiatives could be involved more in R&I calls for Circular Economy[12].

From our analysis, we distil two types of Circular Economy approaches, each linked to two of the pathways presented here: the Coordination & Collaboration pathways and the Circular Business Model pathways. The first is value-chain-focused approaches, which work on the EU level, and the second is industrial site-specific approaches, which work on a local /regional level. Circular Economy approaches to change value chains are good to approach EU-wide, especially when they are focused on making value chains as a whole more circular. An example of this is the European photovoltaics value chain. An interviewee mentioned that especially in these types of projects, where stakeholders from EU-wide or global value chains needed to be brought together, the H2020 funding was well placed to start collaboration for these consortia. When this type of CE approach is needed, a project like the **Coordination and Collaboration pathway** is often seen.

Circular Economy approaches that are based on linking local waste and input streams are actually rather local, at the city, industrial facility, or regional level. These approaches are linked to the **Circular Business Model pathway**. Several interviewees mentioned that one shouldn't attempt to copy-paste these types of Circular Economy approaches when they work for one site specifically, as they might not work for another site with its own local context. On the other hand, for these types of Circular

Economy approaches, capacity building and knowledge sharing between peers at the local level is crucial[13]. This is something that future Framework Programmes could increasingly facilitate.

The importance of **Circular Business Models pathway projects** is also emphasized by the eCorda analysis, as well as in the interviews. As said above, it is shown in the eCorda analysis that Circular Economy is a topic that is of high relevance for the private sector as well. Businesses are among the ones that, in the end, implement Circular Economy approaches.

Regarding the **Material recovery and recycling pathway**, the projects that focus on the material side of the energy transition have gained relevance over the years of the FP. Especially in the later calls, there is increasing attention to this topic. The topic is considered important given that if there are critical materials available for the energy transition from extraction and recycling within the EU, sourcing from third countries is less needed. The eCorda analysis shows that research that is less organisation- or site-specific is more focused on actual research (RIAs) than on facilitating collaboration (CSAs) and is more geographically spread out. This counts, for example, for material recycling research.

With regards to the **Circular Economy policies pathway**, there is a lively debate on what discourse these Circular Economy policies are based on. According to certain researchers, a new EU discourse for R&I policy and Horizon 2020 calls is needed regarding sustainability and economic growth. The new discourse should be founded more on ecological economics and eco-centric approaches. Otherwise, the future Framework Programmes might not be able to actually commit to their objectives of sustainability and Circular Economy[14]. Circular Economy Research calls within Horizon 2020 might not always be aligned with environmental objectives, as the calls still start from the assumption of promoting economic growth[15], even though the assumption that Circular Economy and economic growth are compatible is contested. Researchers who agree with this assumption aim to show that there is a positive correlation between the uptake of the Circular Economy in the EU and economic growth.[16] Researchers who disagree argue that environmental sustainability requires a reorientation towards equitable downscaling of consumption[17]. This debate is also related to differences in dominant Circular Economy-related discourses within the EC.

According to interviewees, increased attention to Circular Economy and new, more eco-centric approaches are already more present in DG ENV and its policies. However, in DG RTD, these new eco-centric approaches are less present as of yet. Therefore, there might be a discrepancy between the policies and the calls for Circular Economy policy projects that DG RTD puts out under the Horizon 2020 FP.

Another challenge related to policies is that current sector-specific policies are often based on the current linear economic systems. This means that Circular Economy approaches can sometimes not be implemented because of policy restrictions, even if research through the Horizon 2020 calls has shown results that a Circular Economy approach is possible. This is especially the case for sectors in which policies have been published in earlier decades when the linear economic model was the standard model. In these sectors, the production phase, the use phase, and the end-of-life phase often all have their own specific stakeholders and policies. However, in a circular economic model, these phases need to be more interlinked. Policies, therefore, are at risk of not being fit for purpose anymore in a circular model.

Overarching the pathways, the main observation is that attention to Circular Economy has increased over the years of the Horizon 2020 FP.[18] However, our analyses show discussion on which topics within Circular Economy should get more attention.

One of the possible reasons for the possible lack of attention to certain topics, which was mentioned by several interviewees, is that there might be **insufficient communication between DG RTD and DG ENV police officers**. Although DG ENV determines the Circular Economy policy agenda to a large extent, DG RTD determines the content of the calls within the FP. Several interviewees mentioned that there could be too little coherence between the policy agenda and the topics and objectives of FPs of DG RTD. On the one hand, what could be done about this is that DG RTD policy officers could put more effort into involving DG ENV policy officers when putting out calls regarding Circular Economy. There are bi-annual meetings between police officers of the two DGs about these calls, but there appears to be room for improvement regarding aligning with Circular Economy policies, as some research calls were (almost) contradicting the policies (about to be) published by DG ENV, which should be avoided. A possible improvement could be to take Circular Economy into account in the evaluation and scoring of project proposals to ensure alignment of the government expenditure. On the other hand, DG ENV policy officers could stay more up-to-date with the research agenda of the DG RTD so they know when to give their input to the DG RTD policy officers.

Another possible reason for these gaps in attention to Circular Economy topics is that **DG RTD is more sector-organized rather than mission-organized**. This leads to Horizon 2020 calls being more sector-organized rather than missions-organized. One interviewee would like to see that the research calls would, in fact, be policy-led and that Horizon 2020 calls should be blue sky research, so even more alignment with the missions of the other DGs should be searched for. A possible solution for this is that DG ENV employees could be (part-time) seconded in DG RTD to produce the calls on Circular Economy together, so policy objectives, as well as policy challenges, can be fed into the calls.

Some researchers and interviewees argue that, even though attention to Circular Economy has increased, the topic still does not get sufficient attention, and/or that certain economic sectors do not get sufficient attention[19]. Topics that are mentioned in the sense that they would not get sufficient attention in Horizon 2020 calls, even though they are a major topic of interest in DG ENV Circular Economy policies, include Biowaste separate collection, Textile waste collection and circular textile value chains, Eco-design for sustainable product legislation, digital product passport, recycling of mixed materials.

15.5. Conclusions

The Horizon 2020 FP has put Circular Economy on the map as an important area for research. The first calls for Circular Economy research started in 2014, with Circular Economy mainly being framed as a waste-related challenge. There was no overarching Circular Economy mission yet that framed the FP calls. Over the course of the FP, the scope of Circular Economy-related calls changed while new Circular Economy policies were formulated. The focus shifted to making value chains more circular from the beginning to the end, as well as to more material integration on industrial sites. The analysis shows that while Horizon 2020 was very valuable in making the first steps to more research on Circular Economy, there are still next steps to be taken for the next FP(s): to take a more holistic view, to focus even more on how Circular Economy thinking can be applied to specific sectors, and to contribute more to the newly created Circular Economy policies.

The coherency of the FP with other policies could be improved: both with Circular Economy-related policies and with sector-specific policies that are still based on linear economic models. To increase coherence with Circular Economy-related policies, a main suggestion from our analysis is that the communication between DG RTD and DG ENV should be improved.

The results of the H2020 projects are generally positive: they have led to more insights into Circular Economy opportunities on the material level, city level and value-chain level. On the material level, new insights have been discovered on the recyclability of materials. At a city level, Horizon 2020 projects supported the exchange of best practices. At a value-chain level, more collaboration for circular approaches has been established within EU-wide value chains. An external factor that was necessary for this success was the involvement of the private sector. Project portfolio analysis shows a relatively high involvement of private sector organisations in the Circular Economy-H2020 projects. This is necessary, given that many of the value chains that need to make the transition to a more circular model are already established value chains. These established private organisations need to be convinced to change their business models, so their involvement is critical. An internal factor that could be improved is to make a proper gap analysis and policy-coherence analysis to show what Circular Economy research is needed. Dissemination and Communication of the project results happened mainly at the end-of-project events with the executive agency RIA, which are seen as good opportunities to showcase the projects. A point of improvement here is that more stakeholders could join these events, especially private organisations that could use the results in their business and policymakers, as their involvement in the events could help improve policy coherence with the H2020 FP. The results also contributed to the Sustainable Development Goals, in particular SDG 12, especially as the last H2020 calls in 2018-2020 explicitly mentioned this SDG in the calls.

International cooperation within the EU has helped the H2020 projects to be successful. Considering that many of the value chains in which circular approaches are most needed are EU-wide or even global, an international approach is needed to make a difference in achieving the environmental objectives of the FP. The analysis did not show that association with third countries is crucial. The steps towards Circular Economy approaches in these calls were mainly focused on within-EU value chains. The EU-added value of the FP is high in the Circular Economy area, considering that many of the value chains in which circular approaches are most needed are EU-wide and therefore benefit from a holistic EU-wide approach. For more local / regional-level Circular Economy approaches, such as industrial-site-specific ecosystems, the EU-added value lies in the exchange of best practices between different sites. The excellence-based approach of H2020 was also helpful: this way, the best universities and experts in the EU work on the Circular Economy calls.

15.6. Annexes

15.6.1. Tables of Horizon 2020 calls analysed

Table 124. H2020 calls analysed.

Work Programme	Call	Topic ID	Total No. Projects
Work Programme 2014-2015	**Waste: A Resource to Recycle, Reuse and Recover Raw Materials. Growing a Low Carbon, Resource Efficient Economy with a Sustainable Supply of Raw Materials.**	SC5-13-2014/2015: Coordinating and supporting raw materials research and innovation WASTE-1-2014: Moving towards a Circular Economy through industrial symbiosis WASTE-3-2014: Recycling of raw materials from products and buildings WASTE-4-2014/2015: Towards near-zero waste at the European and global level SC5-20-2014/2015: Boosting the potential of small businesses for eco-innovation and a sustainable supply of raw materials WASTE-6-2015: Promoting eco-innovative waste management and prevention as part of sustainable urban development SC5-13-2015 Ensuring the sustainable supply of non-energy and non-agricultural raw materials.	27
Work Programme 2016-2017	**Greening the economy.**	SC5-13-2016-2017: New solutions for sustainable production of raw materials SC5-14-2016-2017: Raw materials Innovation actions SC5-15-2016-2017 Raw materials policy support actions SC5-16-2016-2017: Raw materials international co-operation SC5-17-2016: ERA-NET Cofound on Raw materials SC5-25-2016: Macro-economic and societal benefits from creating new markets in a Circular Economy SC5-27-2016: Preparing for pre-commercial procurement (PCP) and/or public procurement of innovative solutions (PPI) in support of climate action, environment, resource efficiency and raw materials CIRC-03-2016 Smart Specialisation for systemic eco-innovation/Circular Economy CIRC-01-2016-2017 Systemic, eco-innovative approaches for the Circular Economy: large-scale demonstration projects" CIRC-03-2016 Smart Specialisation for systemic eco-innovation/Circular Economy CIRC-04-2016 New models and economic incentives for Circular Economy business	45
Work Programme 2018-2020	**Greening the economy in line with the Sustainable Development Goals (SDGs).** **Low Carbon and Circular Industries.**	CE-SC5-01-2018: Methods to remove hazardous substances and contaminants from secondary raw materials CE-SC5-02-2018: Independent testing programme on premature obsolescence CE-SC5-05-2018: Coordinated approaches to funding and promotion of research and innovation for the Circular Economy CE-SC5-07-2018-2019-2020: Raw materials innovation for the Circular Economy: sustainable processing, reuse, recycling and recovery schemes CE-SC5-08-2018-2019-2020: Raw materials policy support actions for the Circular Economy CE-SC5-24-2020: Improving the sorting, separation and recycling of composite and multi-layer materials CE-SC5-25-2020: Understanding the transition to a Circular Economy and its implications on the environment, economy and society CE-SC5-28-2020: Develop and pilot circular systems in plastics, textiles and furniture sectors CE-SC5-31-2020 Develop, implement and assess a Circular Economy oriented product information management system for complex products from cradle to cradle SC5-21-2019-2020: ERA-NET Cofound action for climate action, environment, resource efficiency and raw materials.	30
TOTAL	**5 Calls**	**34 Topics and specific Topic IDs under 5 calls**	**102 PROJECTS**

15.6.2. Identified interview partners

5 interviews have been carried out with policy leads, thematic experts and associations, and beneficiaries of Horizon work programmes. The following list provides an overview of the interview partners for the case study.

Table 125. Interview partners.

Stakeholder Role	Name	Organisation	Rationale
EIT KICs projects partners	Gianluca Avella	Agenzia per L'energia e lo sviluppo sostenibile	Circular Learning Hub/Club AESS designed and realized with ENEA the train-the-trainers and T learning initiatives in this project. It also assisted the co-creation of the virtual reality experiment and of the consequent Circular Economy nudging solutions.
Policy Lead / Expert	Mr Hans-Christiaan Eberl	DG RTD	Circular Economy expert within DG RTD B.1 Circular Economy & biobased systems
	William Neale	DG ENV	Advisor for Circular Economy
Beneficiary	Project representative from	PHOTORAMA	Received support under SC5 calls in 2021 for project "PHOtovoltaic waste management – advanced Technologies for recOvery and recycling of secondary RAw MAterials from end-of-life modules" instrument - IA
Thematic expert	Dr. Sisto, R.	Università degli studi di Foggia	Wrote a paper: Muscio, A. & Sisto, R. (2020). Are Agri-food systems really switching to a Circular Economy model? Implications for European Research and Innovation Policy. Sustainability, 12(14), 5554. url: https://doi.org/10.3390/su12145554 Paper sheds light on public efforts on R&I supporting the transition to the CE, opening a critical debate on the actual relevance of the CE in current R&I policy with its major research policy schemes in the recent programming period of 2007-2013 and 2014-2020.

16. Benchmarking 1: ACRP - Austrian Climate Research Programme

List of acronyms

Table 126. List of acronyms.

Acronym	Meaning
ACRP	Austrian Climate Research Programme
AIT	Austrian Institute of Technology
AWS	Austria Wirtschaftsservice Gesellschaft
BMK	Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology)
CCCA	Climate Change Centre Austria
FFG	Forschungsförderungsgesellschaft (Austrian Research Promotion Agency)
KLIEN	Klima- und Energiefonds (Climate and Energy Funds Austria)
KPC	Kommunalkredit Public Consulting
MoST	(Austrian) Ministry of Tourism and Sustainability
SCHIG	eninfrastruktur Dienstleistungsgesellschaft (rail infrastructure services)

16.1. Executive Summary

The ACRP (Austrian Climate Research Programme) serves as the pilot case and is of specific interest for international benchmarking, whose aim is to identify lessons learnt from best practices worldwide supporting research and innovation and put in perspective the performance of the Framework Programmes in the area covered by the study.

In Phase I, the benchmarking exercise will focus on efficiency and effectiveness, as well as on relevance, and provide a qualitative comparative assessment of H2020 with the four international benchmarking cases which were selected in accordance with the Commission.

The Green Transition is the lens through which the evaluation exercise is regarded. The transition implies a strong connection to society. Therefore, the qualitative comparison with H2020 foresees as dimensions of interest (a) the strategic development, which ought to reflect the adaptive capacity to react to a changing or emerging global situation, (b) the uptake of R&I results, and (c) networking and infrastructure. Transdisciplinarity serves as a fourth cross-cutting dimension.

The ACRP (Austrian Climate Research Programme) is of specific interest for international benchmarking because it explicitly addresses, among others, issues of transformative change and governance, as well as specific support for policy-makers. The pilot case is expected to gauge how well the chosen methodology work and to fine-tune it, if necessary.

This report is a mere snapshot, though, as the comparison with H2020 requires the synthesis results of parallel, ongoing evaluation efforts within the Green Transition Evaluation. Still, it is prepared to absorb those results as soon as they become available and presently captures the key results of the study on the ACRP pilot case. Also, the report offers quantitative results that showcase the ACRP versus H2020 in terms of scholarly output.

16.2. Introduction and overview

16.2.1. Objectives of the international benchmarking

International benchmarking aims at identifying lessons learnt from best practices worldwide, supporting research and innovation, and putting in perspective the performance of the Framework Programmes in the area covered by the study. In Phase I, the benchmarking exercise will focus on efficiency and effectiveness, as well as on relevance, and provide a qualitative comparative assessment of H2020 with the four selected international benchmarking cases.

The ACRP (Austrian Climate Research Programme) serves as the pilot case and is of specific interest for international benchmarking because it explicitly addresses, among others, issues of transformative change and governance, as well as specific support for policy-makers. The pilot case is expected to gauge how well the chosen methodology work and to fine-tune it, if necessary.

The ACRP is under the auspices of the Klima- und Energiefonds (KLIEN; Climate and Energy Funds Austria). It was initiated in 2008 and, according to its legal mandate, emphasises research on nationally relevant forms of impact of global climate change. In addition, it focuses on the analysis and exploration of climate change adaption mechanisms, including interdisciplinary and transdisciplinary dimensions of vulnerability, risk management, and related policies in the field.

16.2.2. Benchmarking approach

Typically, benchmarking involves the following steps, which we adapted for our international benchmarking pilot study: identification of problem areas; identification of similarities with similar interventions in the field; survey of measures and practices; implementation of new and improved practices. Learning and improvement are at the heart of a benchmarking exercise.

The acronym IDEAS captures the action steps of the benchmarking:

- Inquire: investigation of possible benchmarking areas
- Decide: Selection of a relevant area

- Expand: Exploration of key features of the area – causes, effects and solutions
- Analyse: Seeking expert opinions
- Specify: Interpretation of results for the way forward

In the case of the international benchmarking done in Phase 1 of the Green Transition Evaluation, which focuses on ex-post evaluating H2020, two evaluation criteria are key: efficiency and effectiveness. That said, in light of the Green Transition perspective and the paradigm shift that happened during H2020, relevance was added as an additional criterion of interest.

A pool of potential benchmark cases was determined by applying a set of selection criteria. In accordance with the client, four international cases were chosen to be covered by the study (cf. Table 1).

Table 127. International benchmarking cases selected for Phase I of the Green Transition Evaluation.

International Benchmarking	Case	Country	EU	Beyond EU
Case I (pilot)	ACRP – Austrian Climate Research Programme	AT (Austria	✓	
Case II	KLIMAFORSK	NO (Norway)		✓
Case III	FONA – Forschung für nachhaltige Entwicklung (Research for sustainable development)	DE (Germany)	✓	
CASE IV	NSF – National Science Foundation	US (United States of America)		✓

16.2.3. Methodology and case study structure

The ACRP pilot case study follows our international benchmarking methodology, which comprises the following methods:

1. Desk research: evaluation studies of previous years, the online presence of the ACRP, additional background and relevant policy papers about the umbrella institution and its mandate (Klima- und Energiefonds Austria), funded projects, and beneficiaries.

    a. Identification of possible benchmarking areas

2. Internal reviews, identification of interviewees, Selection of relevant areas: In the case of ACRP, we decided to focus on diverging temporalities and overall process scopes between research and applied implementation/transition, how they are dealt with by the KLIEN (Austrian Climate and Energy Funds). More precisely, we looked into the interface between funded research and its impact and coherence with its 120 Climate and Energy Model regions (KEMs) in 1060 municipalities of Austria, concerned with establishing climate mitigation and adaptation projects in the long run. This is justified by a similar, potentially contrasting research purpose approach taken under the FP8 (Horizon 2020) in climate-relevant areas, focusing on green transition (i. e. aiming at initializing structural and lasting change) and, particularly, FP9 (Horizon Europe).

3. Data collection phase: Interviews, focus groups, bibliometric data: We carried out a series of interviews with one of the authors of the 2019 ACRP evaluation study, with the programmatic and operational heads of ACRP and the Climate and Energy Funds, with a member of ACRP's Steering Committee, with relevant member of the National Ministry for Sustainability and Tourism (BMNT), and, finally, with a representative of the Kommunalkredit Public Consulting (KPC) which is responsible for the overall internal handling, screening, and eligibility assessment of research proposals, including outcome and impact monitoring → Expansion with the aim of further identifying good (and bad) practices and understand causes and effects.

    a. All obtained qualitative data will be processed with the purpose of assessing both content and narrative framing – the way certain actors frame issues related to efficiency, effectivity and performance – in order to provide a comparable basis for comparison across benchmarking cases.

    b. The qualitative data were complemented by and interpreted in the light of the results of a quantitative analysis undertaken by Science-Metrix, and an additional desk research analysis involves expert opinions and quantitative data to further complement and increase the robustness of the objectives of the evaluation results.

4. Dimensions for qualitative comparison with H2020: given that the lens of the overall evaluation exercise is the Green Transition, which implies a strong connection to society, the following dimensions for the qualitative comparison with H2020 are foreseen:

    a. strategic development, adapting to changing/emerging global situations

    b. uptake of R&I results

    c. networking and infrastructure

    d. transdisciplinarity as a cross-cutting dimension

16.2.4. Study constraints

For this benchmarking pilot study, several constraints were to be taken into account. First, the ACRP and its operating entity, as of yet, KPC, have no direct mandate for proper programme monitoring. That is, neither are encompassing statistical data collected on an annual basis nor are any other measures of progress made available publicly. There is a list of data regarding outcomes and follow-up procedures circulating internally between KPC, KLIEN, and BMK, but access to this list has not been granted. Second, the ACRP at KLIEN is grossly understaffed and, thus, in many regards, operationally and programmatically run part-time by a single person.

That said, the outcomes of the evaluation study 2019 with regard to the ACRP's overall performance provided us with concrete entry points for our semi-structured interviews with members of the management board and steering committee. We understand that given our overall theme of green transition and climate change adaptation/mitigation, a focus on improving social impact through effective communication, differentiated objectives, and targeted instruments is vital. Therefore, we focused during interviews on the highlighted improvement areas to pinpoint and identify lessons learnt and potential benchmarks for similar funding programmes in Europe.

Guiding questions for the interview of stakeholders as well as a list of interviewees are included in the annex.

In addition, we conducted an in-depth analysis of the material and (rather rudimentary) research project database available online. This includes the so-called KLIEN "guidelines", which set the stage for every annual call of the ACRP and present some of the thematic focuses, as well as their shifts over the years in response to (mainly) public policy interests.

16.3. Synthesis of evidence

16.3.1. Introduction to the international benchmarking pilot case: the ACRP

The Austrian Climate Research Programme (ACRP) is the first in a series of four international benchmarking cases and, as such, our pilot case.

The ACRP is under the auspices of the Climate and Energy Funds Austria. It was initiated in 2008 according to its legal mandate, which emphasises research on nationally relevant forms of the impact of global climate change. In addition, it focuses on the analysis and exploration of climate change adaption mechanisms, including interdisciplinary and transdisciplinary dimensions of vulnerability, risk management and related policies in the field.

16.3.2. ACRP background

The Austrian Climate Research Programme (ACRP) is one of the main funding programmes of the Austrian Climate and Energy Funds (KLIEN) and is deeply committed to achieving climate neutrality by 2040 and, by 2030, to generate 100 % of the nationally consumed energy by renewable resources. KLIEN supports the implementation of the goals of domestic climate policy and the development towards a sustainable energy system. The four intervention areas of the Fund are:

- Energy transition
- Mobility transition
- Climate Change
- Awareness Raising

Since its establishment in 2007, the KLIEN (Climate and Energy Funds) has developed around 111 different funding programmes. The Fund also participates in the SOLAR-ERA.NET. KLIEN is supported by operational funding and research agencies such as the Austrian Federal Promotional Bank (aws), the Austrian Research Promotion Agency (FFG), and others.

16.3.2.1. Legal basis and governance

The legal basis for ACRP is the RTD Guidelines according to § 11, subparagraphs 1 and 2 of the Research and Technology Funding Act of the Federal Ministry of Transport, Innovation and Technology as amended on January 1, 2015, and extended by the Federal Ministry of Climate action in 2020. The programme owner is the Climate and Energy Fund (KLIEN). The ACRP calls are currently operatively implemented by the Kommunalkredit of Public Consulting GmbH (KPC). To be precise: Until June 2022, the operational organization of calls, submission handling, peer reviews and funding payments has been in the hands of KPC, an external agency linked to the private and public sector, which for years has also been in charge of running the operations and funding disbursements of several KLIEN programmes and activities. The knowledge of and proximity to, the scientific community – in particular of the carefully extended project proposal peer reviewers' database – at KPC has been built up over the years, ensuring stability and proper follow-up procedures by maintaining the main responsibility for administration and operation within the hands of the same few persons (almost) since the first round of calls of the ACRP.

16.3.3. Thematic orientation of ACRP

ACRP supports research on the impacts of climate change on ecosystems, specific economic sectors, health, social aspects, etc. and the resulting adaptation requirements, including inter- and transdisciplinary vulnerability studies, risk management approaches and policy analyses. The program aims to enhance Austrian research competence in the area of climate adaptation and mitigation and to integrate it more strongly into international research endeavours. The ACRP is by far the largest research programme of its kind in Austria.

16.3.4. ACRP objectives and KLIEN (Klima- und Energiefonds)

The ACRP focuses on research on climate change and climate actions, adaptation, mitigation, and their mutual interrelation. The intent is to provide scientific background for the implementation of the Austrian strategy for adaptation to climate change, the National Energy and Climate Plan, and the Paris Agreement in Austria.

These objectives require concerted efforts across all sectors for enormous rethinking and transitioning towards different energy-related economic and social models, of which the KLIEN (Klima- und Energiefonds; Engl. Climate and Energy Funds) is fully aware. Located at the BMK (Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology), KLIEN aims at propelling novel climate-friendly measures, including energy-saving technology and climate change adaptation, as well as mitigation, between emerging so-called model regions at the provincial administrative level (Bundesländer), municipalities and urban spaces within Austria. The ACRP emerged out of a semi-private initiative from the scientific community reclaiming research space and funding within the KLIEN in 2008. In this regard, both KLIEN and ARCP, according to its General Managers, aspire to deliver innovative beacons for the national and international community in the field of climate protection, yet "made in Austria".

16.3.5. ACRP Target group

The programme targets different kinds of research organisations and science-oriented organisations. Research areas include, among others, natural sciences, social and economic sciences, and legal and technical topics that usually have to be solved in interdisciplinary and partly also transdisciplinary ways. Project partners are not limited to Austrian research institutions and can include foreign researchers as well as businesses and other practitioners as long as full publication of results is guaranteed.

16.3.6. Previous evaluations and lessons learnt

The ACRP has been evaluated at the national level in 2009 and 2019. Both studies present relevant basic data for this international benchmarking pilot exercise, in particular, the 2019 evaluation study, which positively highlights the ACRP's performance related to the constant interaction between the steering committee during the project cycle, which aims at further improving research outcomes; on the other hand, this could be negatively perceived as exerting control. This interaction has been described by some interviewees as unique in that other international funding programmes in the field do not have it (Evaluation study 2019, chapter 6.3). Negative findings refer to the weak overall monitoring of data and outcomes, in addition to science communication – these, so the study conclusion, should be improved by fostering the ACRP's governance structure. This is particularly relevant since some of the ACRP's funding pillars explicitly aim at the creation of guidelines and handbooks for decision-making that are rather loosely made available and, back in 2019, were not broadly promoted/communicated at a societal level later on. In addition, while being esteemed as socially highly relevant, the ACRP's research output has been described as being in conflict with internal university and academic performance assessments, which typically focus on article publications (only).

In 2020, the ACRP´s management board responded to earlier criticism from the Ministry of Tourism and Sustainability (MoTS) – which generally claimed little say in the steering committee – by including two permanent experts from the ministry. This way, political or at least governmental influence has been strengthened rather than diminished. Yet, this influence has clearly not extended as far as selecting research proposals or themes to be funded, as the 2019 study underscores.

Generally, the 2019 evaluation study's main findings listed the following improvements as recommendations for the next years without spelling out priorities:

- Overall budget increase after a programmatic shift from fewer long-term funded research to more mid-term funded projects in 2018.

- Differentiation of programme objectives, particularly with regard to capacity-building, practice relevance, and evidence-driven information for (political) decision-making.

- Expansion and differentiation of funding instruments, especially for fostering research communication and long-term availability of results, to foster impact.
- Refinement of the selection procedures, including measures for applicants at different career stages and reviewers from outside traditional academic settings.
- Governance structure
- Communication, with an emphasis on differentiation according to the respective key stakeholders in the decision-making processes.

16.3.7. Relevance

Arguably, according to international policy recommendations (IPCC, EU Green Deal, etc.), the overarching objective of climate and climate impact research is, beyond data collection and periodic updates thereof, to actually and concretely contribute to the green transition, the achievement of the Sustainable Development Goals (SDGs) and, in the case of Austria, to fulfilling the National Climate Adaptation Strategy.

In this sense, the BMK's KLIEN and its funding pillars are uniquely positioned by combining and working across the public, private, and research sectors. It launched, for instance, an internationally recognised vanguard strategy, including the aim of 100 % renewable energy by 2030. Energy should be sourced from the centralised and de-centralised origins, for which climate and energy communities are key. Legal and structural provisions (funding, networks, adoption of policies, etc.) have been met to realise this declared objective.

According to our interviews, and this has been confirmed across all our interviewed stakeholders, the ACRP is, however, rather detached from these hands-on transformation initiatives at the Austrian sub-federal and municipal levels. While there have been a few projects in the past whose results and outcomes were relevant for climate adaptation projects and energy communities – especially from the social sciences, e. g. interrogating motivations for subscribing to public green transition credits and related consumer decisions – the ACRP and its strategic orientation is aligned with the excellence aspirations of the scientific community rather than concrete applied transformation requirements and public policy in the field.

In other words, there is little cross-breeding and influence between the ACRP and KLIEN's overall programmes. Reasons are certainly linked to diverging needs of scholarly work and excellence aspirations in relation to socio-political realms. But they are also part of what we analysed as a foundational tension, as well as a deeper-lying social conflict over very concrete interests and economic positioning. For instance, concrete service-providing attempts by CCCA scientists at the municipal and provincial level have rapidly got under attack, because of being perceived as threatening the thematic leadership of BMK's expert, on the one hand, and on the other, the interests of local businesses of transition advisers and related services, frequently attached to, or under the influence, of local politics and its immediate interests.

There is also another dimension of unmet relevance which needs to be addressed: while the ACRP has managed to establish and foster a relevant scientific community, little has been done to better implement and embed the ACRP and related KLIEN research funding (Energy, Smart Cities, START, etc.) between larger international funding and exchange programmes, in particular, by the European Union. But also beyond, since climate change – from an organic perspective of autopoietic systems (e. g. Maturana and Varela, 1975) – is indeed of global concern. Mutual climate impact and interlinked effects require to be studied from a systemic planetary perspective, as highlighted by several approaches, most famously those following the approach of planetary boundaries (Rockström et al., 2009). Several of our interlocutors confirmed that international partnerships within ACRP-funded projects are regularly limited to the European research landscape and also thematically narrow (e.g. almost not including research related to the oceans due to Austria being a landlocked country).

This certainly reflects diverging policy priorities and interests between the multilateral and national funding levels. For instance, Austria still lacks complementary public budget provisions and further temporary staff-reserving mechanisms for co-funding large EU research and adaptation projects, as our expert interviewees from the ministries pointed out. Also, within universities, large-scale EU-funded research with an extremely competitive positive approval rate is during the proposal preparation phase frequently perceived as unnecessarily binding staff and resources with highly uncertain outcomes.

Yet, in the sense of bringing about a green transition, we argue that this situation also points to necessary improvements with regard to better integration of and interconnection with international and national and regional research programmes, as well as applied transition projects. Additionally, this would involve a much better, transparent public monitoring and knowledge-transfer mechanism of the ACRP, for instance, in order to achieve full socio-political relevance and thus also increase media attention.

16.3.8. Effectiveness

The focus of the program is on research on the national characteristics and effects of climate change, including the adaptation requirements to inter- and transdisciplinary vulnerability studies, risk management approaches and policy analysis. In a somewhat uneasy combination, it aims to satisfy several needs according to its stakeholder community: The program aims to (a) improve Austrian research competence; (b) expand this sector and involve it more closely in international research, and (c) to deliver the decision-makers in politics and administration scientifically sound evidence-based decision-making insights.

To do so, the ACRP has – until 2021 – published 14 competitive annual Calls and supported over 250 projects with a total volume of approx. 100 million Euro. Each call results in approx. 80 to 90 proposal submissions.

This tension plays out at several levels of the ACRP's overall performance. To name just a few examples that emerged through our interviews:

- Divergent temporalities and needs: while policy-makers require quick assessments and answers, ACRP-funded, excellence-oriented projects last on average for three years (and are frequently perceived as too short for delivering excellent scholarship, particularly after the project period reduction of 1 year in 2020). However, according to our policy interlocutors, also three years would mostly be too long according to their specific needs and requirements. In response to this tension, in 2022, "ACRP Impact" was launched to fill the gap of much-needed short-term applied projects, responding to emerging knowledge voids. ACRP Impact should, in addition, serve as a second preliminary testing site for larger ACRP proposals later on.

- Project size, innovation and orientation: In a similar vein, the SC has a track record of rejecting projects based on criteria of absolute scientific innovation or novelty, not necessarily according to national standards of novelty (i. e. permitting the replication of a certain study design or methodology for the Austrian context). In addition, accepted projects typically involve a focus on the international scientific community beyond national frontiers, while the funding entity seeks to maintain a pro-Austrian focus according to its specificities and needs. Accordingly, policymakers would favour a number of smaller and quicker projects instead of larger and more international projects – a tendency observed by our interlocutors also for the European research funding level: scientist community members clearly declared their interest against larger European funding if only leading to larger consortia and longer projects, and as being generally in favour of strengthening national funding programmes, taking regional specificities into account and presenting lower entry levels for younger scholars, if this tendency continues.

- Independence versus political influence: Scientific excellence requires political independence and non-interference. However, policy-making, especially within a generally still rather hostile policy environment regarding pro-evidence-based decision-making, requires safeguarding certain spaces for proposing thematic priorities and launching specific calls or direct channels of communication with researchers. The specific construction of the ACRP manages to strike a delicate balance between these different logics and realms but cannot escape constant criticism regarding seemingly, too little effort between its main stakeholder groups given this basic tension. In response, for instance, KPC's operational processing will be handed over to the Austrian Research Promotion Agency (FFG). FFG is the single national funding and handling agency for publicly commissioned or tendered research, yet in fact, oriented towards industrial research and pro-business development in Austria. The effect of this transition on the ACRP is yet to be seen. However, some of our interlocutors are already alert to a changing perception within the climate research community, alluding to losing ownership – and thus overall relevance – with regard to "their" research platform.

In conclusion, the ACRP's tools and instruments were evaluated in 2019 as both sufficiently effective (in terms of achieving to foster a relevant scientific community and their competencies) and insufficiently effective at the same time, given the (overly) broad mandate of the programme. This is furthermore complicated by the country's predominant policy and research focus on pro-technological and, mostly, pro-market-based adaptation in the field of climate change responses and less on mitigation itself, not to mention the Green Transition.

16.3.9. Efficiency

As regards the evaluation of project proposals, a first check for formal criteria is being conducted by KPC staff members upon proposal submission. Next, those not satisfying the formal criteria are sent back for resubmission within close deadlines, resulting in a regular acceptance rate of almost 100 %. In the third step, proposals are grouped thematically, upon which the KPC proposes three reviewers (out of its database) for each proposal. Project teams are called upon to provide the name and contact of a fourth reviewer, who is double-checked by KPC and then entered into the database for the next year's call.

Finally, KPC submits its proposals to the SC and KLIEN, who review the proposed reviewers and, if necessary, make changes to the pre-selection. KPC, then, is in charge of contacting the reviewers and processing the review phase, including payments and communications to the project applicants. After reviews, positively reviewed projects need to be approved by the SC – which, according to some of our interviewees, tends to select rather "conservatively" according to the overweight of the natural sciences and generally less "innovatively". The BMK receives only the anonymised abstracts of selected and not selected projects for funding and can issue additional recommendations but has no vote in the approval process. Most importantly, the SC is said to decide according to scientific excellence standards and not necessarily according to policy needs in any given political, environmental or economic cycle. There is a relevant exception, though, and this concerns foremost the direct calls for national climate assessments enacted through the ACRP's annual calls, which were developed under the influence of the presence of IIASA in Austria, and the membership of several of its staff members in the Intergovernmental Panel on Climate Change. The proposal success rate over the years is between 20 and 30%, highlighting the competitive character of the programme.

In terms of limited in-house monitoring, funded projects have to submit an interim report and a final report (both made publicly available on the ACRP website). In addition, all funded projects are voluntarily called upon submitting an outcome report one year after the finalization of their projects. This data is stored internally only.

The ACRP was evaluated after its 3rd call and again after its 9th call. According to these evaluations, the thematic scope of the ACRP has remained stable over the years. At the same time, the fundamental tension between its two main objectives seems to have intensified: Fostering excellence in academic research and networking, on the one hand, versus providing relevant evidence to acute problems and challenges to decision-makers.

This is aggravated by the following issues: First, the ACRP represents the sole relevant funding programme in the field of climate and climate impact research in Austria, particularly including an interdisciplinary and even transdisciplinary problem-oriented scope. Other major science funding institutions in Austria are primarily focused on basic research according to disciplinary excellence and, overwhelmingly, based on single-scholar career profiles. Also, contrary to neighbouring Switzerland and Germany, the national meteorological institution (ZAMG) in Austria plays no role in research funding or infrastructure at all beyond the provision and hosting of climate data.

Second, the understaffed ACRP team within KLIEN and the ACRP's institutional set-up between SC and Advisory Board (currently suspended and to be renewed in 2022) can only guarantee a certain level of scientific excellence but cannot ensure greater social visibility and relevance of climate research as such in times of accelerated climate change and urgently required encompassing deep green transitions. According to the 2019 evaluation study, the current steering model of the ACRP is overstrained with issues of agenda-setting and ensuring socio-political relevance.

One of the key successes of the ACRP is the establishment and cultivation of a highly interdisciplinary steering committee.

16.4. Preliminary short comparative analysis

The international benchmarking foresees a short qualitative comparative analysis of the study case with H2020. Since the ACRP is a pilot case and the H2020 evaluation effort is still ongoing, the synthesis of results for comparison is not available yet – they are expected to be ready in autumn 2021. For this reason, the international benchmarking cases will be prepared for such a comparison, and this section will be updated as soon as possible.

16.4.1. Strategic development

In terms of strategic development, the key question is whether the programme kept abreast with and adapted to changing or emerging global situations, such as the Paris Climate Accords. In this regard, the ACRP fares quite well – its intent is to provide scientific background for the implementation of the Austrian Strategy for Adaptation to Climate Change, the National Energy and Climate Plan, and the Paris Agreement in Austria.

While efforts towards the Green Transition have not been scaled up – in relative terms – by the ACRP as they have within H2020 (through the Green Deal), the former has indeed reacted to the shifting policy landscape. Although the ACRP highly stimulates interdisciplinary research, it could be argued that it does not go far enough to foster transdisciplinary research to establish deep connections to societal actors.

16.4.2. Uptake of R&I results

According to our interviewees, there are several relevant fields where the ACRP cannot deliver but would, in principle, be well-positioned to do so. These fields have been identified by both our expert interviewees as urgently required in order to substantially foster the green transition but to be fair, neither exists at the European funding level so far (which has likewise been critiqued). The identification of these required action fields starts from in our conversations frequently repeated premise that there would (rather) not be a further lack of knowledge in the field of climate and climate impact research but rather of socio-political and economic unwillingness to take unpopular or evidence-driven decisions (from policy-makers down to individuals):

- There are no funding mechanisms in place for improving the precise identification of concrete problems between decision-makers and the scientific community, to which further research should reply to. This void, however, is substantial since different stakeholder voice their concerns in different terms and jargon, thereby losing precision in posing questions and stating problems to be effectively addressed.

- Climate change, mitigation and adaptation are immensely complex, transdisciplinary challenges which would require much more participative approaches to knowledge-making, knowledge transfer and policy-making. Eventually, they involve a series of social and particularly ethical questions addressing social, economic and political values and priorities (including fears, hopes, and expectations), which are so far, however, frequently left out (especially if review panels are staffed with scientists from the hard sciences only). It would be required to open up review panels in the field to, for instance, policy experts from other countries, city and municipality administrations and other relevant fields (e. g., arts) in order to foster knowledge transfer but also citizen engagement and participation more broadly.

- Arguably, research within more participatory structures – e. g. with cities, municipalities and other forms of public administration – does not follow a systematic approach in two ways: First, with regard to the selection of consortium partners, since there are no databases available tracking the most excellence or knowledgeable ones in the field. Selection, therefore, follows other criteria, such as acquaintance or established working relations, yet occasionally ignoring already achieved excellence elsewhere. Second, knowledge obtained through funding remains all too often locked in the drawer, i. e. kept in an internal report or journal article for the scientific community only. This critique is far from being new. However, what should be conceived, also within EU research frameworks, would be novel funding mechanisms for ensuring post-project knowledge transfer and exchange across project consortia, as well as, in the case of Horizon Europe, across municipality/city, etc. partners, including the private and public sector.

The words of one of our interlocutors, “Climate research in Austria has enabled us to establish proper structures (strategies, funding, work programmes, etc.), but we still don’t know how to use them properly […]”, are especially significant with regard to the broad relevance and efficiency for ensuring a deep green and structural transition.

16.4.3. Networking and infrastructure

The ACRP’s unique institutional set-up, its stakeholder dialogue, the fact that there is indeed such a niche research programme in Austria beyond large-scale public funders such as the Austrian Science Fund (FWF), and the frequent inter- and transdisciplinary approach chosen by the funded projects, have all tremendously contributed to community building in Austria, in the area of climate research.

Structurally speaking, though, the ACRP has few cross-programmed links to other activities and funding initiatives, even at KLIEN, with the notable exception of the KLAR! Climate adaptation pillar. Given that the ACRP indeed should or could produce relevant knowledge for more applied and governance-related knowledge – if enabling or contributing to achieving the green transition was part of its primary objectives – effectivity seems to underperform to a certain degree when looking at the broader picture (beyond scholarly excellence). It could do more in terms of enabling communities relevant to making the Green Transition goals a reality and (help) creating climate services.

While community-building within climate research has worked well, and while some climate services have started to emerge, their scope and scale are too limited to substantially contribute to a Green Transition in Austria.

16.5. Preliminary implications in relation to H2020

The same limitations stated in the previous sections apply here, i. e., parallel H2020 evaluation efforts are still ongoing, and the synthesis of results for comparison is not available yet. Following the same approach as the comparative analysis of the main comparison dimensions, the implications of the scrutiny of the evaluation criteria relevance, effectiveness, the efficiency will be prepared in this section for the actual comparison of H2020. This section will be updated as soon as the synthesis evaluation results are available.

16.5.1. Relevance

According to science community members and policymakers alike, mitigation has been the focus of the ACRP in earlier years, but this focus shifted more recently also because of the adoption of the Austrian Strategy for Adaptation to Climate Change in 2013. This keen strategy has been lauded as far-reaching and encompassing, yet concrete measures and impact are clearly lacking behind, especially at the federal level. Policy-makers have, therefore, an interest in achieving concrete adaptation success, also reflected by the KLIEN programme “KLAR!” targeting adaption model regions in Austria. It is not by coincidence that, according to our KLIEN interlocutors, thematically open ACRP research outcomes are receiving the most attention within the KLAR! The programme, while otherwise being rather irrelevant for the majority of KLIEN’s applied transition and transformation programmes. In terms of knowledge transfer, some of the ACRP-funded projects are featured in a BMK/KLIEN in-house publication, circulating among the various KLIEN initiatives, but supposedly, according to our interviewees, rather rarely taken up by concerned potential partners.

Therefore, from a Green Transition perspective, ACRP’s relevance can only be regarded as average. With regard to climate research, the relevance of ACRP would be regarded as considerably higher.

16.5.2. Effectiveness

As stated above, the final assessment regarding the effectiveness criterion will be provided as soon as the synthesis results of parallel ongoing H2020 evaluation studies are available. For the time being, a quantitative comparison based on scholarly output, i. e. publications in scientific journals, conference proceedings, books, etc., offers several insights. These quantitative results were provided by Science-Metrix, based on a tailor-made analysis of the publications that can be linked to the ACRP or to H2020.

To benchmark the ACRP against H2020, the statistically robust findings are presented along the following dimensions:

1. International co-publication output

- The average number of unique countries per publication in H2020 publications was always above the corresponding figures found in ACRP publications at statistically robust levels.

- In terms of shares of authorships, H2020 publications tended to have lower proportions of EU27 and EU27+UK authorships than ACRP publications. H2020 publications, however, had higher shares of authorships taken up the RIS, Associated Countries, and Third countries aggregates than those found in ACRP publications (for instance, a normalised share of RIS authorships at 15.7, against 4.6 for ACRP papers).

- Combined together, findings on the 1) ICR, 2) the average number of countries per paper, and 3) the average share of authorship per paper indicators do suggest a more internationalised and diverse profile in co-authorship for H2020 papers as compared to ACRP papers.

2. Cross-disciplinary research

- Most differences between H2020 and ACRP scores on cross-disciplinarity indicators are not statistically robust. That said, measurements for both H2020 and ACRP publications on these dimensions are above the world level, with scores between 1.2 and 1.6.

- On the normalised share of highly multidisciplinary publications, H2020 publications score well below ACRP publications at 1.4 (against 2.2). ACRP's score on this dimension is exceptionally high. The stability intervals for this comparison fall just outside the 95% threshold, however, ruling out any definitive conclusion.

3. Science-industry co-publications

- A share of 20% of H2020 publications included both academic and private firm authors, against 14% for ACRP publications. The added value of H2020 funding on this dimension was not statistically significative, however

4. Citation Impact

- Note that only about 60% of ACRP publications and 45% of H2020 publications in the analysis here had been published in 2019 or before and, therefore, could be included in the citation impact assessment.

- Citation impact performances were much higher in Austrian H2020 publications against ACRP publications on all indicators considered, although H2020's lead was not statistically definitive.

- Most clearly, the H2020 score on the citation distribution index (CDI) was much above that of the ACRP publications (37 to 19; remember that the world level on this specific indicator is set at 0). The CDI indicator is a particularly robust citation indicator that takes into account performances by all papers in a given publication set, whereas other citation impact indicators can sometimes reflect exceptionally high performances by outliers.

- H2020 performances are more than nine times the world level for the share of publications falling within the top 5% most cited publications in their respective subfield (HCP1% indicator). This compared to a share that was three times the world level for ACRP publications.

5. Gender equality in authorships

- H2020 publications included at least one female author in 86% of cases, against 62% of ACRP publications, a statistically significant lead for H2020 funding.

- Authorships on H2020 publications were taken up by women in 28% of cases, against 25% of cases for ACRP publications. H2020's lead is not significant here.

6. Open access

- A proportion of 90% of H2020 publications were available under an open access modality, against 60% of ACRP publications. H2020's lead was statistically robust.

7. Policy-related uptake

- The normalised share of H2020 publications cited in policy-related documents was 12 times the world level, against less than nine times the world level for ACRP publications. This H2020 lead was not statistically definitive.

- For both H2020 and ACRP publications, policy-related uptake is well above world levels, indicating strong performances for this type of societal outcome.

- It can be noted that policy-related mentions of peer-reviewed publications should normally be allowed a four-year citation window or more, which has not always been the case for the publications assessed here.

8. Beyond academia

- In terms of altmetrics, differences in performances between the H2020 and ACRP publications sets are not statistically significant.

- Both H2020 and ACRP publications recorded levels of altmetric mentions ranging from two to six times the reference levels in a given subfield and year (except for Wikipedia mentions to ACRP publications). That is, both H2020 and ACRP publications are likely to have been associated with greater levels of effort to increase awareness and online attention towards the findings they contain.

To sum up the key results of the quantitative analysis:

- Austrian H2020 publication performances were well above world level and had, in general, a lead over ACRP in terms of a) the share of publications with at least one female author, 2) the citation impact, and 3) open-access publishing.

- Austrian H2020 publications recorded more internationalisation and diversity in country participation than ACRP publications (the computation of world-level referents is not straightforward for these indicators, though).

- Both Austrian H2020 publications and ACRP recorded similar high scores well above word level in terms of 1) policy-related uptake, 2) altmetrics 3) the share of science-industry co-publications.

- H2020 publications, while still scoring slightly above world levels on cross-disciplinarity indicators, scored equal to or below ACRP publications.

- In terms of gender equality, H2020 publications scored close to both the world level and ACRP level for the publication-level share of authorships taken up by women.

Globally speaking, the ACRP performs well in terms of the scholarly output that is generated, enabled by its funding. In terms of achieving its goals, the programme shows a fairly high rating.

It should be stressed here that, based on the study results – considering the ACRP evaluation results and the expert interviews conducted – the uniqueness of the ACRP is that it accommodates a broad range of interests and ensures highly interdisciplinary research.

16.5.3. Efficiency

In terms of efficiency, the ACRP fares well: given its constraints, it manages to process a rather large number of projects quite efficiently and even managed to grow and expand over the course of several years, e. g. with regard to launching the new ACRP Impact funding mechanism. Furthermore, certain solutions to the persistent criticism of different stakeholders were found, e. g. the inclusion of the BMK experts in the SC (steering committee) sessions (subject to the right of the SC to sit temporarily without BMK members if desired) and their voice (but not vote) in the selection of topics for the annual call guidelines and other focuses of the KLIEN overall programme.

Based on study results, ACRP's efficiency can be rated as high.

16.6. Annexes

16.6.1. Guiding questions for stakeholder interviews

Welcome, introduction to the evaluation exercise, and introduction of the interviewee.

A) top-level management:

1. What could EU research funding in the field of climate and adaptation learn from the ACRP?

2. We would like to ask you about your personal/institutional perception regarding the ACRP´s performance over the past years, especially in light of its socio-political objectives (e. g. raising climate change awareness).

3. Can you identify some of the most relevant success stories?

4. Is the ACRP engaged in its own benchmarking exercises of other comparable funding programmes in the field (Switzerland, Norway, etc)?

5. What has been the management's response to the main findings of the 2019 evaluation study?

6. Could you describe to us the institutional and strategic strategy/coherence linking the ACRP to further Klimafonds programmes, such as Klimabüdnis and regions?

7. What are the main solutions to support/enable/channel research follow-up into concrete transition measures, e. g., at the level of Klimaregionen projects?

8. What do you believe to be required from the policy side to enable lasting green transition effects?

9. What would be the ACRP's role in this process?

10. What are the thematic and administrative links between ACRP and Austria Wirtschaftsservice as well as Kommunalkredit Public Consulting?

11. Do they have a voice in defining overall strategies, goals and/or selection of research funding?

12. To which extent is the Ministry included in these tasks, and is its voice given weight?

13. What about your (the ACRP's) institutional perception regarding efficiency (in terms of funding objectives) and effectiveness (regarding overall programme delivery)?

14. Is there any identifiable strategy regarding the embedding of ACRP within European research funding programmes and objectives?

15. Where would you see strengths/weaknesses of the ACRP in terms of its embedding with the overall funding programme landscape in Austria…

16. .. in Europe?

17. What would you need in order to foster both Austrian climate-related research, as well as European linkages?

18. At the Klima and Energiefonds, as well as at the Ministry, who is in charge of the overall strategy?

2nd part:

a) Do you think that the ACRP has been delivering as expected in the area of climate change adaptation and green transition?

b) How would you rate its relevance for Austria (scale 1 to 5) and compared to European funding in this area (1 to 5)?

c) Could you describe to us what has triggered/caused the most significant ACR programme changes since 2009?

d) What would be needed to increase research impact and lasting change?

e) In which ways is the ACRP replying to these challenges?

f) How does collaboration work in the field of climate-related research in Austria between the ACRP and other institutions, FFG, FWF, etc?

g) Has this collaboration seen any changes over the past years? If so, why…?

h) Hard facts: data on research patents? Publications (Q1/Q2)? Follow-up projects? Networking events? Students graduated? Further outcomes?

i) Is there any systematic research outcome follow-up procedure?

j) Do you prefer re-funding of already successfully established research consortia?

B) mid-level programme coordinator level:

1. What could EU research funding in the field of climate and adaptation learn from the ACRP?

2. First off, we would like to ask you for your own and institutional perception about the ACRP´s performance over the past years, especially in light of its socio-political objectives (e. g. raising climate change awareness)?

3. Could you please describe to us the institutional and strategic strategy/coherence linking the ACRP to further Klimafonds programmes, such as Klimabüdnis and regions?

4. What are the main solutions to support/enable/channel research follow-up into concrete transition measures, e. g., at the level of Klimaregionen projects?

5. What do you believe to be required from the policy side to enable lasting green transition effects?

6. What would be the ACRP’s role in this process?

7. In which ways is the ACRP replying to these challenges?

8. How do you internally assess the effectivity regarding goal achievement and efficiency (programme delivery)?

9. What are the thematic and administrative links between ACRP and Austria Wirtschaftsservice as well as Kommunalkredit Public Consulting?

10. Do you think that the ACRP has been delivering as expected in the area of climate change adaptation and green transition?

11. How does collaboration work in the field of climate-related research in Austria between the ACRP and other institutions, FFG, FWF, etc?

12. Which changes has this collaboration seen over the past years? If so, why…?

13. Hard facts: data on research patents? Publications (Q1/Q2)? Follow-up projects? Networking events? Students graduated? Further outcomes?

14. Is there any systematic research outcome follow-up procedure?

15. Do you prefer re-funding of already successfully established research consortia?

16.6.2. ACRP Interviews and list of interviewees

During the first half of April 2022, we conducted a series of 10 semi-structured online interviews with ACRP, Ministry, and KPC staff, as well as with Steering Committee members and relevant scientific community members with ACRP work experience. Each interview took roughly 30 to 90 minutes and followed a set of guiding questions for the different scenarios comprising public and private interlocutors. Our questions generally followed the idea of having our interviewees themselves assess the ACRP's strength and success stories, in addition to its overall efficiency, effectiveness, and relevance.

We also aimed at capturing those socio-political obstacles which prevent the deeper structural changes necessary to bring about the "green transition" and the role of publicly funded science in this process. Strategies for better knowledge generation and, thus, public policy input were collected from our interviewees.

All interviews were recorded, transcribed, and qualitatively analysed. The overall response rate was very positive, taking into account the extreme time pressure of this pilot study; some interviewees preferred to remain anonymous with regard to their answers to our study.

Table 128. List of ACRP interviewees.

Acronym	Meaning
Mr. Ingmar Höbarth	KLIEN co-director
Mr. Jürgen Schneider	BMK director general Climate Action and Energy
Mrs. Barbara Kronberger-Kiesswetter	BMK coordination Climate Politics
Mrs. Eva Dvorak	KLIEN Energy Communities
Mrs. Biljana Spasojevic	KPC operational coordinator ACRP
Mr. Stefan Duscher	Ministry of Education, Science and Research

Mr. Gernoth Wörther	ACRP Programme manager at KLIEN
Mr. Helmut Hojesky	BMK head of unit Climate and Energy
Mrs Brigitte Tiefenthaler	Lead author of the ACRP evaluation study published in 2019, Technopolis
Mrs. Helga Kromp-Kolb	Leading climate scientist in Austria, a former member of the ACRP Steering Committee and coordinator of the CCCA

17. Benchmarking 2: KLIMAFORSK – Norwegian climate research programme

17.1. Summary

The KLIMAFORSK (Norwegian Climate Research Programme) is of specific interest for the international benchmarking (in the Framework of Evaluation of Green Growth aspects within Horizon 2020), which aims to identify lessons learnt from best practices worldwide supporting research and innovation and put in perspective the performance of the Framework Programmes covered by the study.

In Phase I, the benchmarking exercise will focus on efficiency and effectiveness, as well as on relevance, and provide a qualitative comparative assessment of H2020 with the four international benchmarking cases which were selected in accordance with the Commission.

The Green Transition is the lens through which the evaluation exercise is regarded. The transition implies a strong connection to society. Therefore, the qualitative comparison with H2020 foresees as dimensions of interest (a) the strategic development, which ought to reflect the adaptive capacity to react to a changing or emerging global situation, (b) the uptake of R&I results, and (c) networking and infrastructure. Transdisciplinarity serves as a fourth cross-cutting dimension.

Overall, it can be concluded that efforts towards the Green Transition have been scaled up in the case of KLIMAFORSK; however, lagging behind Horizon 2020. Especially the transdisciplinarity aspect and collaboration with industry will be tackled much better by Horizon 2020.

The KLIMAFORSK (Norwegian Climate Research Programme) is of specific interest for international benchmarking because it was decided to select two from countries beyond EU borders (one larger and another one –smaller) for benchmarking studies. Next to that, the availability of information also played a role in the selection. KLIMAFORSK is, thus, representing the selection of a smaller country (Norway) outside the EU.

This report is a mere snapshot, though, as the comparison with H2020 requires the synthesis results of parallel, ongoing evaluation efforts within the Green Transition Evaluation. Still, it is prepared to absorb those results as soon as they become available and presently captures the key results of the study on the KLIMAFORSK case, including quantitative results that showcase the KLIMAFORSK in terms of scholarly output.

17.2. Introduction and overview

KLIMAFORSK is among a series of four international benchmarking cases performed in the context of the evaluation of the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness - Focus on activities related to the green transition.

The international benchmark of KLIMAFORSK is based on extensive desk research, interviews with key stakeholders, such as evaluators of KLIMAFORSK, policymakers, representatives of the Research Council of Norway and members of the programme board, and bibliometric analysis.

17.2.1. Benchmarking approach

Typically, benchmarking involves the following steps, which we adapted for our international benchmarking pilot study: identification of problem areas; identification of similarities with competitors in the field; survey of measures and practices; implementation of new and improved practices. Learning and improvement are at the heart of a benchmarking exercise.

The acronym IDEAS captures the action steps of benchmarking:

1 **I**nquire: investigation of possible benchmarking areas

2 **D**ecide: Selection of a relevant area

3 **E**xpand: Exploration of key features of the area – causes, effects and solutions

4 **A**nalyse: Seeking expert opinions

5 **S**pecify: Interpretation of results for the way forward

Proper benchmarking needs to define the areas, baselines and criteria according to which the benchmarked entity will be assessed. In our case, two criteria are highlighted as of primordial relevance: **efficiency** and **effectiveness**. In addition, we hold that relevance, coherence, and impact (the most difficult to access) are likewise relevant in order to gain an encompassing estimation of the overall performance and process.

17.2.2. Objectives of the international benchmarking

Overall, the aim is to assess the performance, understood as a long-term process, of KLIMAFORSK in the light of its encompassing policy environment. This means assessing best practices for achieving real impact, ideally positive change, at the level of municipalities, policy-making at the level of the concerned ministry, and/or the relevant research community, which KLIMAFORSK expressly seeks to enhance, deepen, and foster at the national level, and, in a second step, between the national level and its ties to international partners, institutions, and networks.

17.2.3. Methodology and benchmarking structure

The methodology for our international benchmarking case KLIMAFORSK comprises the following methods:

a) **Desk research**: evaluation studies of previous years, the online presence of KLIMAFORSK, additional background and relevant policy papers, funded projects and beneficiaries.

    a. **Identification of possible benchmarking areas**

b) **Internal review:** identification of interviewees and **selection of relevant areas**: In the case of KLIMAFORSK, we decided to focus on evaluators, policymakers and programme and board managers, with the assumption that they would provide the most relevant views.

c) **Data collection phase**: Interviews, bibliometric data: We carried out a series of interviews with the above-mentioned interviewees with the aim of further identifying good (and bad) practices and understanding the causes and effects.

    a. All obtained qualitative data were processed with the purpose of assessing both content and narrative framing – the way certain actors frame issues related to efficiency, effectiveness and performance – in order to provide a comparable basis for comparison across benchmarking cases.

    b. The qualitative data were complemented by and interpreted in light of the results of a quantitative analysis undertaken by Science-Metrix and additional desk research. The analysis involves expert opinions and quantitative data to further complement and increase the robustness of the objectives of the evaluation results.

d) **Analysis:** Analysis of the collected data to assess the scores for KLIMAFORSK in the following areas:

    a. Effectiveness = level of smooth achievement of KLIMAFORSK's own goals, objectives and purposes

b. Efficiency = value for money in terms of wider societal and policy impact (research output as an intermediary step)

c. Impact = Research output of KLIMAFORSK funding

d. Relevance = relevance attributed by the external analysts (ourselves) to the KLIMAFORSK program pillars, according to their respective objectives and purposes, in addition to impact and coherence.

17.2.4. Study constraints

For this benchmarking pilot study, several constraints were to be taken into account. Aside from KLIMAFORSK's evaluation report, relatively few sources of information were available. It should be noted that the evaluation report did provide sufficient information. In addition to that, while the people who contributed to the study were of much help and a broad range of stakeholders were interviewed, there were some difficulties in arranging an adequate amount of interviews. Among the reasons that were mentioned were their own availability and the timing of the interviewing period.

Overall, the data available are considered sufficient for the purpose of analysis. Guiding questions for the interview of stakeholders as well as a list of interviewees are included in the annex. In addition, we conducted an in-depth analysis of the material and (rather rudimentary) research project database available online.

17.3. Synthesis of evidence

17.3.1. Introduction to the international benchmarking case KLIMAFORSK

In 2013, the RCN (Research Council of Norway) established the Large-scale programme KLIMAFORSK to foster excellent climate research and build the bridge between climate science, public policy and society. KLIMAFORSK succeeded NORKLIMA, the initial Large-scale programme focused on climate research. In 2019, KLIMAFORSK was integrated into the Climate- and polar research portfolio of the RCN as the RCN changed from Large-scale programme-management to active portfolio management.

KLIMAFORSK was one of several RCN programmes funding fundamental climate research in Norway. As explained, KLIMAFORSK's activities are now integrated into RCN's Climate- and polar research portfolio. KLIMAFORSK is mainly financed by the Ministry of Climate and Environment and the Ministry of Education and Research. Previously, the Ministry of Agriculture and Food (until 2016), and the Ministry of Trade and Industry (until 2018) also partially funded KLIMAFORSK. KLIMAFORSK has been managed by RCN as executive agency since its inception in 2013 as the successor of NORKLIMA which itself dated back to 2004.

17.3.2. Thematic orientation of KLIMAFORSK

The objective of KLIMAFORSK was to promote excellent climate research and foster the translation to other parts of society, such as public policy and the general public. In order to achieve this, three scientific objectives formed the basis of KLIMAFORSK. Specifically, the programme aimed to increase knowledge about the following topics:

- Natural and anthropogenic climate change (SO1)
- The impacts of climate change on nature and society (SO2)
- The transition to a low-emission society and adaptation to climate change (SO3)
- A clear emphasis can be seen on both the scientific side as well as the need to integrate the social side in order to support the societal adaptation to climate change.

17.3.3. KLIMAFORSK target group

Due to the fact that KLIMAFORSK was a Large-scale programme, its scope included different types of academic research, ranging from fundamental research to applied research. The target group of KLIMAFORSK consists therefore of a broad range of scientists, stemming from ocean or terrestrial research to humanities and social sciences.

17.3.4. Legal basis and governance

The programme harkens back to its predecessor NORKLIMA, the first of the so-called Large-scale Programmes created in 2004. In 2012, RCN evaluated the Norwegian climate research.[155] This evaluation pointed out that Norwegian research on climate was of excellent quality and that Norwegian research groups clearly contributed to national and international research, but that an overarching focus was lacking and most research groups acted individually. Therefore the evaluation recommended to establish an overarching Large-scale programme that also included the humanities and social sciences aspect. Furthermore, the document *The knowledge base for a new climate initiative in the Research Council* combined the results of other preparatory work that was done for the establishment of KLIMAFORSK, a committee was set-up to draft the work programme and finally a public consultation was held.[156]

Both the KLIMAFORSKS Programme Board and the Programme administration performed tasks that supported the strategic actions and day-to-day activities of KLIMAFORSK. The Programme Board was responsible for the strategic priorities and instruments for achieving KLIMAFORSK's objectives. The Programme Board 2013-2019 consisted of ten members from universities, institutes, industry, and government agencies in Scandinavia. The Programme administration was responsible for operations and administrative follow-up of projects under the programme. The programme administration consisted of a programme coordinator assisted by personnel with scientific and administrative expertise.

17.3.5. Instruments

KLIMAFORSK is mainly based on calls for proposal. KLIMAFORSK was responsible for or participated in 45 calls. In total 15 out of the 45 calls were in collaboration with other Large-scale programmes (e.g. MARINFORSK, MILJØFORSK, and POLARPROG). In addition to that, KLIMAFORSK contributed with 7 out of the 45 calls to international collaborative calls (e.g. Belmont Forum and JPI Climate).

Based on the three thematic scientific objectives, KLIMAFORSK implemented a three year-cycle of annual KLIMAFORSK calls. This means that on a rolling basis the main annual call had the focus on either 1. Climate Systems (SO1); 2. Impacts (SO2); or 3. Transition (SO3). The main aim for this set-up is to create consistency for relevant research groups.

Aside from the main annual thematic call, there was also a possibility for research groups to apply for the so-called 'Free Climate Research' (FRIKLIM) calls, which occurred three times (in 2014, 2016 and 2019). FRIKLIM calls are not linked to thematic specificities, but need to achieve high-quality research that is both bold and innovative.

During the period 2014-2020, KLIMAFORSK allocated ~ 1,369 bn NOK (~ 140 m €) to 296 projects. Seven different project types exist to cover a wide range of objectives. KLIMAFORSK's main project type is the *Researcher Project*, which is aimed to contribute to important new insights, scientific publication, researcher training and international research collaboration. In total 132 funded projects belong to the category *Researcher* Project. There were in total 22 FRIKLIM *Researcher Projects*, which also received additional funds from other RCN budgets in 2014 (to strengthen excellent projects) and 2019 (to strengthen excellent projects and humanities.

The other instruments are Collaborative Projects (i.e. researcher projects with user participation), Communication and dissemination projects, Guest Research Scholarship, Scholarship for research stays abroad, and Support for events, and other projects. The mix of different types of ways that the

[155] Research Council Norway, 2012, Norwegian climate research: an evaluation.
[156] Kunnskapsgrunnlag for en ny klimasatsing i Forskningsrådet 2012

programme can select projects to fund creates a unique mix of a top-down thematic perspective and a bottom-up open approach.

17.3.6. KLIMAFORSK objectives

The KLIMAFORSK work programme states as primary objective the promotion of outstanding climate research and the generation of essential knowledge about the climate for the benefit of society.

As previously mentioned, this objective is operationalised along three scientific objectives:

(1) Natural and anthropogenic climate change (SO1)

- Observations and process understanding
- Climate variability and change
- Modelling climate evolution at the global and national level.

(2) The impacts of climate change on nature and society (SO2)

- Impacts of climate change on the physical and chemical environment
- Impacts of climate change on ecosystems
- Interactions between drivers and feedback effects on the climate system
- The consequences of climate change for infrastructure, trade and industry and living conditions.

(3) The transition to a low-emission society and adaptation to climate change (SO3)

- Questions relating to both mitigation and adaptation
- Questions relating to reducing GHG emissions and increasing carbon sequestration
- Questions relating to adaptation
- Questions relating to interactions between mitigation and adaptation

However, in addition to the scientific objectives, KLIMAFORSK was also set up to contribute to broader non-research related objectives, the so-called structural objectives. There were seven structural objectives:

- Promote cooperation and task distribution in climate research
- Encourage boldness in scientific thinking and scientific innovation in research projects
- Enhance the international profile and contribution of Norwegian research groups
- Foster the development of a new generation of climate researchers
- Expand expertise and applicable knowledge in society
- Facilitate targeted communication and dissemination activities
- Increase the use of available data and research infrastructure

17.3.7. Previous evaluations and lessons learned

KLIMAFORSK was evaluated in during the period 2020-2021. The main goal of the evaluation was to gather information on the achievements and lessons learnt from KLIMAFORSK. Based on the evaluation, valuable input could be provided for the newly established Climate- and polar research portfolio and recommendations could be developed for the development of future climate research priorities.

The most important conclusion from the Evaluation Committee is that KLIMAFORSK realised its main objective of promoting outstanding climate research and providing knowledge about the connection between climate (research) and the benefits for society. As a result of KLIMAFORSK, researchers were able to better understand climate (change) and potential effects that are caused by it on society. According to the Evaluation Committee, the majority of the objectives have been achieved. This was driven mainly by the annual call with changing themes, the FRIKLIM calls, the contributions to joint national and international calls, and research infrastructures. Both the predictability by the already announced themes of the annual calls as well as the FRIKLIM calls were mentioned by multiple interviewees as very important components of the success of KLIMAFORSK. In terms of impact, it should be noted that most of the research results are of high quality but also incremental.

Regarding the need, identified by the 2012 evaluation of Norwegian climate research, to unite the Norwegian climate research groups, the Evaluation Committee concludes that through KLIMAFORSK activities are sufficiently coordinated. With respect to the contributions of individual research activities, the Committee mentions that these are rather incremental and that outstanding scientific achievements are exceptional. Yet, KLIMAFORSK and the research groups have been vital in building and maintaining Norway's status as a leading country in climate research, which is exemplified by the strong contributions to IPCC and other international fora.

17.3.8. Recommendations from the 2021 evaluation

Following the evaluation, the Evaluation Committee has formulated several recommendations that should be considered for the implementation of the Climate- and polar research portfolio and future climate research policy. The recommendations are structured along three lines: research themes and focus areas; implementation and programming; and indicators, monitoring, and evaluation. The Committee does not prioritise recommendations, however two recommendations stand out.

First of all, while KLIMAFORSK's work programme was developed before the launch of the 2030 Agenda and the 17 Sustainable Development Goals (SDGs), it important that these should be integrated into the research programmes and/or portfolios. Second, the Evaluation Committee mentions that outstanding research often is caused by interactions between different scientific disciplines and sectors. It therefore recommended that inter- and transdisciplinary research takes a prominent place in future climate research.

17.4. KLIMAFORSK benchmarking results

17.4.1. KLIMAFORSK benchmarking results

The foundation of KLIMAFORSK was based on an evaluation of the Norwegian climate research as commissioned by the RCN. While the research stemming from Norwegian climate research groups was of excellent quality, the evaluators pointed out that an all-encompassing focus in the Norwegian climate research landscape was missing. In this spirit, the objective of KLIMAFORSK also touches upon these two points, namely to support excellent research and promote the translation of this research to society.

Both the 2021 evaluation as well as interviewees point out that generally speaking KLIMAFORSK has achieved the overarching objectives. The interviewees agree that KLIMAFORSK was an important and successful programme. One of the important reasons for the success is the operational set-up of KLIMAFORSK. In general, the KLIMAFORSK programme board was responsible for setting up the strategy for KLIMAFORSK. On an annual basis, the overall direction of KLIMAFORSK (i.e. strategic priorities, research needs, etc,) were assessed by the Board. This process was driven by annual research needs that were compiled by the funding Ministries and discussed with the programme Board. This process was operationalised through both the recurring calls-system and an open call-system. The recurring calls were centered along the three thematic priorities. On a rolling basis, one of the three topics is chosen as the subject for the annual call. Aside from that, the so-called free calls (i.e. FRIKLIM) also existed, where researchers were free to submit call related to one of the three topics without a specific predetermined topic. According to our interviewees this set-up provided clarity for the researchers, which was regarded positive part of the programme. By knowing what is coming, it allows research groups to build a long-term planning as they are aware of when they can apply for funding.

In terms of the topics themselves, the three topics (and sub-topics) include the full spectrum of climate research. The topic Natural and anthropogenic climate change is both vital to understanding the climate change at the national level as well as at the global level. By observing the climate over a longer period and modelling the evolution accordingly, researchers provide the basis for any other climate-related research. However, as climate change already is changing nature and has its impact on society, the other topics also cover the actual effects of climate change on nature and society and measures to adapt to climate change. Interviews confirmed the good coverage of climate change-related research topics. With regards to FRIKLIM, while on the one hand there is no doubt that the existence of the free calls is positive as it by definition funds out-of-the-box proposals, some interviewees mentioned that more innovative projects could have been funded through this call. On the one hand, it is more difficult to assess these calls as compared to regular calls, as they usually are covering more disciplines and riskier which makes the calls more difficult to assess. However, on the other hand, often these projects are bolder and can potentially lead to relatively more impact.

In terms of impact, the projects that fall under the first topic – climate modelling – are regarded as instrumental to the Norwegian and global climate modelling community. Researchers and research groups are well-integrated in the global community as is exemplified by their contributions to the IPCC. Through these prominent positions, Norwegian researchers have an influence on the national and international debate. As previously mentioned, the research results were of high-quality, but also incremental. This was also echoed by interviewees. KLIMAFORSK, the RCN and the relevant ministries also annually discussed the research needs for the coming years. In combination with the representatives of the different stakeholder communities in the programme board, the research priorities of KLIMAFORSK always stayed relevant for multiple stakeholders and not only for science.

However, there were difficulties to find the balance between fundamental research and more applied research, which actually tries to solve the problems or come up with adaptation measures. This is also linked to the difficulties with integrating humanities and social sciences into the calls and/or projects. While the evaluation of KLIMAFORSK concludes that the number of projects that include humanities and social sciences is rather big, it was mentioned by several interviewees that in their opinion, the amount of projects including humanities and social sciences was not sufficient. According to these interviewees, in this perspective KLIMAFORSK was lagging behind how Horizon 2020 has tackled this issue. Nevertheless, in the Climate- and polar research portfolio that has replaced the research programme a strong focus is placed on integrating humanities and social sciences.

The same explanation holds true for inter- and transdisciplinary research supported by KLIMAFORSK. While the evaluation considers KLIMAFORSK efforts to promote inter- and transdisciplinary research to be satisfactory, several interviewees mention that this is very important, especially in the context of climate (change) research. Through the FRIKLIM calls (i.e. the open calls), these inter- and transdisciplinary projects were supported as it specifically was set-up to fund high-quality projects that are bold in their scientific approach and innovative. Indeed calls that are structured this way provide the highest potential to fund projects that are potentially very impactful (in scientific, societal or economic terms). The objective of these FRIKLIM projects was achieved, however interviewees mentioned that those deciding which calls are funded could have allocated more funding to these special calls.

With regards to the funding of KLIMAFORSK, as previously mentioned, it was mainly funded by the Ministry of Climate and Environment and the Ministry of Education and Research. Furthermore, there was additional funding from the Ministry of Agriculture and Food and the Ministry of Trade, Industry and Fisheries (from respectively 2014-2015, and 2014-2018), however these amounts were relatively little. Funding coming from the Ministry of Climate and Environment increased over the years, whereas funding coming from the Ministry of Education and Research decreased over the years. Generally, the total annual funding remained the same over the years (ca. 150 NOK Million or 15 Million EUR). According to interviewees, however, there was an expectation following the introduction of KLIMAFORSK that over the years the funding would rise, which not happened. Other interviewees mentioned that this type of research has been low on the priority list and therefore KLIMAFORSK had to deal with relatively smaller budgets as compared to other research programmes. However, it was also noted that more and more the topics that are covered by KLIMAFORSK's scope are becoming more important as the priority to research climate change becomes higher (e.g. international developments such as SDGs and EU Green Deal).

Finally, an important part of the research process are the communication and dissemination efforts of the research activities. The facilitation of these activities were included as a structural objective of KLIMAFORSK. Projects funded by KLIMAFORSK are required to engage in communication efforts in order to foster the dialogue between different stakeholders. There was also a targeted call for communication projects, specifically to inform the general public. The evaluation concluded that KLIMAFORSK was generally successful in facilitating the communication and dissemination of research outcomes. This was the most successful for the research community, but to reach the general public is more difficult. As was mentioned by one of the interviewees, to reach society at large one should be creative and not only write a short piece on the research.

17.4.2. Quantitative benchmarking of KLIMAFORSK

The following quantitative benchmark of KLIMAFORSK was prepared by Science-Metrix. It compares KLIMAFORSK and H2020 with each other and to world averages from several perspectives: International co-publication output; cross-disciplinary research; science-industry co-publications; science-industry co-publications; citation impact; gender equality in authorships; open access; policy-related uptake; and indicators beyond academia.

International co-publication output[157]

On most international co-publication indicators, KLIMAFORSK is lagging behind as compared to Horizon 2020. However, considering the scope and size of KLIMAFORSK, this was expected.

A share of 87% of H2020 publications were international co-publications, against 69% for KLIMAFORSK publications. The differential increase brought about by H2020-funding is therefore close to 19 percentage points.

A proportion of 49% of H2020 publications were written by at least one EU27 researcher as either first, last or corresponding author, against 20% in KLIMAFORSK publications. Again, this differential increase is fully expected given the status of Norway as Associated Country. The share of publications rises to 63% when considering the EU27+UK aggregate, capturing the many collaboration linkages between Norway and the UK.

A proportion of 14% of H2020 publications were international co-publications with contributions from an author from a RIS country as either the first, last or corresponding author. This share was 3% for KLIMAFORSK papers.[158]

Findings on collaborations with researchers from other Associated Countries are statistically inconclusive. This finding also complicates the interpretation of findings in collaboration with ERA-based researchers.

A proportion of 35% of H2020 publications were international co-publications with contributions from an author from a Third Country as either first, last or corresponding author. This share was 29% for KLIMAFORSK papers, but the differential increase brought about by H2020 funding was not statistically definitive. The differential increase on the share of authorships from third countries was statistically robust, however, at +5 percentage points (from 18% in KLIMAFORSK publications to 23% in H2020 publications).

The average number of unique countries per publication in H2020 publications was always above the corresponding figures found in KLIMAFORSK publications at statistically robust levels.

While differential increases in unique EU27 countries involved in international co-publications were expected, H2020 publications by Norwegian researchers also saw increases in the average number of involvement by other Associated Countries (from 1.4 to 1.8 per paper) and Third Countries (from 1.0 to 1.9 Third Countries involved on average per paper).

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[157]It should be kept in mind that Norway is an Associated Country that falls within the ERA aggregate but not the EU27 aggregate. Any participation in H2020 projects or publications therefore increases its share of co-publications with EU27 researchers by definition.

[158] It should be noted however that this formulation of the indicator may be biased against KLIMAFORSK publications, since KLIMAFORSK funding is likely not directly available to RIS country researchers, whereas H2020 funding is.

The combination of these observations is that, on average, H2020 publications by Norwegian researchers recorded authorship from 6.0 distinct countries on average, whereas this figure was 3.3 for KLIMAFORSK publications by the same Norwegian authors.

Cross-disciplinary research

H2020 did not induce any differential change in deployment of cross-disciplinarity practices as compared to their KLIMAFORSK publications. Norwegian researchers' publications tended to be slightly below world level in terms of multidisciplinary[159], at either 0.8 or 0.9 (world level is 1.0). Norwegian researchers' publications tended to be below world level on the interdisciplinarity[160] indicator, at 0.6 and 0.7.

Norwegian researchers' publications tended to be well below the world level for their share of publications falling with the top decile of most interdisciplinary papers in their respective subfield and year (DDR10%), at 0.1 and 0.3.

Science-industry co-publications

A share of 7.2% of H2020 publications included both academic and private firm authors, against 0.1% for KLIMAFORSK publications. The added value of H2020 funding on this dimension was statistically definitive, but note that the differential gain measured (+6.5 percentage points) differs slightly from the simple subtraction of the two empirical measurements because of sampling processes applied as part of the bootstrapping.

Citation impact[161]

The H2020 score on the citation distribution index (CDI) was much above that of the KLIMAFORSK publications (31 to 20; remember that the world level on this specific indicator is set at 0). The CDI indicator is a particularly robust citation indicator that takes into account performances by all papers in given publications set, whereas other citation impact indicators can sometimes reflect exceptionally high performances by outliers

Gender equality in authorship

H2020 publications included at least one-woman author in 79% of cases, against 65% of KLIMAFORSK publications, a statistically significant lead for H2020 funding. Authorships on H2020 publications were taken up by women in 25% of cases on average, against 22% of cases for KLIMAFORSK publications. H2020's lead is not significant here.

Open access

A proportion of 95% of H2020 publications were available under an open access modality, against 90% of KLIMAFORSK publications. H2020's lead was statistically robust.

Policy-related uptake

The normalized share of H2020 publications cited in policy-related documents was 12 times the world level, against three times the world level for KLIMAFORSK publications. This H2020 lead was statistically definitive. For both H2020 and KLIMAFORSK publications, policy-related uptake is well above world levels, indicating strong performances for this type of societal outcomes.

It can be noted that policy-related mentions of peer-reviewed publications should normally be allowed a four-year citation window or more, which has not always been the case for the publications assessed here. The sparsity of observations available on this indicator may somehow inflate normalized effect sizes.

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[159] Average of the relative diversity of disciplines in the research backgrounds of different authors of a given publication - DDA indicators.
[160] Average of the relative diversity of disciplines in the references of a given publication – DDR.
[161] Note that only about 87% of KLIMAFORSK publications and 37% of H2020 publications in the analysis here had been published in 2019 of before and therefore could be included in the citation impact assessment. Because of this situation, most differential changes recorded were not statistically definitive.

Beyond academia

Citation windows for uptake of peer-reviewed publications in patents is often set at seven years or more, an interval that has not yet elapse for the H2020 and KLIMAFORSK publications considered here. Unsurprisingly given this, no observation of citation from patents was recorded for either publication sets.

H2020 publication by selected Norwegian authors received six times more than expected coverage in at least one journalistic outlet, against twice the expected level for KLIMAFORK publications. This differential gain was statistically robust, but again, effect sizes tend to be inflated by general sparsity of altmetrics mentions. For the remaining altmetrics dimensions considered here, differences in performances between the H2020 and KLIMAFORSK publications sets are not statistically significant.

On all four dimensions, both H2020 and KLIMAFORSK publications recorded levels of altmetric mentions ranging from twice to four times the reference levels in a given subfield and year. That is, both H2020 and KLIMAFORSK publications by selected Norwegian researchers are likely to have been associated with greater levels of effort to increase awareness and online attention towards the findings they contain.

To sum up the **key results** of the quantitative analysis:

Norwegian H2020 publication performances were much above world level and at a clear led to KLIMAFORSK achievements on the dimensions of 1) average number of distinct countries of affiliation per publication 2) share of academic-private co-publications; and 3) share of publications with at least one woman author 4) citation impact as captured by the CDI 5) uptake in the policy-related literature 6) coverage in journalistic outlets; and 7) share of publications available in OA.

Both Norwegian H2020 publications and KLIMAFORSK recorded high scores much above world level on 1) average of relative citations 2) shares of highly cited publications 3) altmetrics.

Publications by selected Norwegian researchers, irrelevant of H2020- or KLIMAFORSK-funding status, scored below world levels on cross-disciplinarity indicator, without any marked differential change brought about by H2020 funding.

It should be noted that many interviewees stressed that the RCN really supports Norwegian research groups in their applications for H2020. Therefore strong Norwegian researchers and research groups are likely to participate in innovative and important H2020 projects.

17.5. Assessment of the benchmarking results

17.5.1. Effectiveness

Our evidence shows that KLIMAFORSK is an effective research programme. Considering the original reason why KLIMAFORSK was founded (i.e. individually excellent research groups, but no overall guidance), KLIMAFORSK managed to create coherence within the climate research landscape in Norway. The topics covered by KLIMAFORSK not only exploit the strengths of Norwegian climate researchers (e.g. climate modelling), they also cover a broad range of relevant topics (i.e. fundamental climate science, and the impacts and adaptation measures). The research outputs by the Norwegian researchers are internationally well-regarded. The findings of bibliometric analysis confirms this. Furthermore, due to outstanding reputation of the Norwegian climate research community, the input from Norwegian researchers is respected both at the European as well as international level (e.g. JPI and IPCC), according to the interviewees. Norwegian researchers or research groups that want to participate in Horizon 2020/Horizon Europe are supported by the RCN in order to receive funding.

While the research programme is effective, there are several factors hindered achieving the maximum potential of KLIMAFORSK. For instance, the extent to which cross disciplinary and interdisciplinary research is implemented is supported could be higher. This is reflected in the bibliometric analysis as well as mentioned by several interviewees who see the efforts of H2020 to achieve this as exemplary. The aim of the FRIKLIM instrument was to facilitate bold and innovative projects. As these projects can be riskier, interviewees mentioned that sometimes the committees deciding whether or not to fund the application could have granted more promising innovative projects. In addition to that, the integration with industry was also not always optimal. Reason for this include the existence of other

RCN programmes specifically focused on business-oriented research and the exclusion of projects that are focused on the development of technologies. In general, KLIMAFORSK interacts well with other RCN programme (or nowadays portfolio) by co-funding projects.

Two factors that also had an impact on the effectiveness are related to the changing general context for climate change (research). When KLIMAFORSK was founded, there were relatively few overarching frameworks to tackle these global issues. Since then the 2030 Agenda and the 17 Sustainable Development Goals have been established as well as the EU Green Deal. In the new Climate- and polar research portfolio, these topics have been integrated better. The introduction of these international goals and policies also show that over the years climate change (research) has become higher on the agenda. In Norway, the same holds true. Some interviewees indicated that at the start of the programme it seemed that much more funding would be dedicated to the type of research that is supported by KLIMAFORSK. However, in reality policymakers preferred to dedicate funding to research programmes that also focused on technological developments. Both factors fall generally outside the sphere of influence of KLIMAFORSK, but they indeed hindered the effectiveness of the research programme.

17.5.2. Efficiency

Regarding the proportionality of costs to benefits of the research programme KLIMAFORSK, it can be said that KLIMAFORSK is an efficient research programme. With a moderate level of resources, KLIMAFORSK managed to produce excellent scientific output supporting a wide range of stakeholders.

In the context of climate research, it is difficult to compare the costs to the benefits of the programme, as the benefits of the climate research – especially for fundamental research – is often built on long-term observations. In addition to that, the research outcomes are often complex and difficult to explain. Even though dissemination of the results are part of the structural objectives – and this went well – the dissemination to all relevant stakeholders remains a difficult task.

Nevertheless, interviewees indicated that, given the context, the KLIMAFORSK output was excellent. Also specifically with regards to cost-effectiveness, the organisational set-up (i.e. annual call with different themes) contributed to the efficiency as part of the process was standardised. This also means that the free calls were considered less efficient. However, this argument touches upon the previously mentioned struggle between the differences in advantages and disadvantages of the annual thematic rotating calls and the free calls. Interdisciplinary and multidisciplinary projects often bring along more impact to society and science itself, however the applications and outputs of these projects are much more difficult to assess.

One of the previously mentioned points – that the interaction with the industry was not always optimal and a better integration would have led to a more effective programme – also holds true for the efficiency. All stakeholders are needed for a well-supported green transition. Industry is very important player as well, so better interaction with industry could have led to insights and technological developments needed for a smooth green transition.

Nowadays the RCN uses a different approach to funding research programmes, namely a portfolio approach instead of a programme approach. It should be noted that this is not due to the workings of KLIMAFORSK, but it was a general policy shift at the RCN.

17.5.3. Relevance

KLIMAFORSK is a research programme that is highly relevant to both Norwegian society as well as the research community on a regional, national and global level. The topical approach covers all aspects of doing research in the context of climate change. By providing the basic needs of climate research (the topic climate modelling), it lays the foundation of the more applied topics of identifying the impacts of climate change and means of climate change adaptation. While the actual implementation of the free calls could have been better, it is still a highly valuable assets as it opens up the opportunity for projects that do not necessarily fit the requirements of the pre-determined topics, but might be interesting due to the quality or multidisciplinary nature. At the time of the introduction of KLIMAFORSK, the programme anticipated well on the emerging needs for research relevant for the green transition. Unfortunately, the funding of KLIMAFORSK was not always as high as expected, as expressed by interviewees, which hindered achieving the full potential of KLIMAFORSK.

Norway is an ‘Associated Country’ and therefore participates in Horizon 2020, but has limited ability to influence the decision making-process with regards to the research direction due to their absence in the European Parliament and the European Council. However, due to the prominence and reputation of Norwegian researchers in climate research, the input of Norwegian researchers and research outcomes stemming from KLIMAFORSK projects are highly regarded at the international stage. Furthermore, as interviewees pointed out, many of the research topics that are important in Horizon 2020 are similar to those important for Norway.

As for the embeddedness in Norway itself, the programme board included representatives of the different Norwegian user communities, for instance stemming from government agencies and the Norwegian Environment Agency. This ensured that different perspectives are taken into account and therefore the research aligned with policy and societal needs. In addition to that, there were the annual talks with relevant Ministries for research needs that the Ministries deem to be important for their own topic and therefore should be covered by the KLIMAFORSK calls. While KLIMAFORSK and the Norwegian climate research community have a good reputation internationally, in the near future it could improve the connections with the region (i.e. Scandinavia) to gain a better understanding of the regional dynamics of climate research.

In terms of the relevancy of KLIMAFORSK with regards to future research needs, attention for fundamental climate research is rising, as well as for related topics such as biodiversity, is rising as is exemplified by the European Green Deal and the EU Biodiversity strategy for 2030. As previously discussed, the SDGs were not included in the original KLIMAFORSK set-up, but this was due to the fact that the SDGs were not yet launched. Research supported by the newly established Climate and polar portfolio is considered to be vital to achieving the SDGs. KLIMAFORSK is therefore highly relevant for future research needs. The long running climate modelling research can be considered a great asset.

One of the structural objectives was also to expand the expertise and applicable knowledge in society. KLIMAFORSK aimed to include a wide variety of stakeholders, such as citizens and businesses, in the projects. Some topics covered research that could be fed into local, regional or national policymaking. For some types of projects, namely the collaborative projects, involving the users community was required. KLIMAFORSK therefore aimed to fund research that is relevant to society. The evaluation of KLIMAFORSK also concluded that the use of research-based knowledge has increased as a result of KLIMAFORSK. The integration with businesses went less smooth. KLIMAFORSK is on this topic lagging behind Horizon 2020.

While the FRIKLIM calls indeed were designed to facilitate innovative and bold projects, the funding of these projects could have been more ambitious as was indicated by interviewees and the bibliometric analysis. Especially the cross- and interdisciplinary topics could have been supported more. This, however, also holds true for the H2020 projects with Norwegian researcher. It therefore seems something not specific for KLIMAFORSK, but more to the entire Norwegian climate research community.

17.5.4. Good practices

The specific organisational set-up where there are three pre-determined themes that on a rolling basis are have an annual call and there is also a chance to apply for funding for more innovative out-of-the-box projects in the FRIKLIM call.

KLIMAFORSK also keeps its strategic priorities up-to-date through its programme board and through the annual discussions on research needs with the relevant policymakers. By evaluating annually, it is able to keep its focus on the right topics.

Aside from the scientific objectives, KLIMAFORSK also has the so-called structural objectives, which focus on a wide range of topics that all contribute to developing benefits in general and to society and the research community. Some of these structural objectives are integrated into the calls and types of projects (e.g. collaborative projects and communication and dissemination projects), which act as a means to achieve the structural objectives.

KLIMAFORSK has an important international aspect where international collaboration is promoted (e.g. joint international calls). Promoting the international profile of research groups was also one of the structural objectives.

17.6. Short comparative analysis

The international benchmarking foresees a short qualitative comparative analysis of the study case with H2020. KLIMAFORSK represents one of four case studies, and the synthesized 2020 evaluation effort is still ongoing; thus, the results for the overall comparison are not available yet (expected to be ready in late autumn 2022) and will be provided in an overall comparison across all benchmarking cases. However, the ACRP pilot already established four cross-cutting evaluation dimensions, which should be addressed in all benchmarking cases.

17.6.1. Strategic development

In terms of strategic development, the key question is whether the programme kept abreast with and adapted to changing or emerging global and national situations, such as the Paris Climate Accord and other international commitments.

From the start of the programme, three major topics were used as leading themes. These three topics covered the spectrum from fundamental climate modelling to the impacts of climate change and measures that need to be taken to adapt to climate change. Annually, the priority themes were discussed with policymakers, making sure that the right topics got funded. Nevertheless, according to the interviewees, more could have been achieved if the importance of KLIMAFORSK had resonated more on the political level, which at the time focused more on science than focused on technological output.

While KLIMAFORSK's work programme was developed before the launch of the 2030 Agenda and the 17 Sustainable Development Goals (SDGs), the evaluation committee of KLIMAFORSK indicated that these should be integrated into coming programmes. This does not mean that the topics were not covered, only that the framework was not integrated. KLIMAFORSK also considered and learned from developments at the European level, also with regard to Horizon 2020.

Overall, it can be concluded that efforts towards the Green Transition have been scaled up in the case of KLIMAFORSK. Efforts by Horizon 2020 can be regarded as more successful. However, KLIMAFORSK developed positively over time.

17.6.2. Uptake of R&I results

It should be noted that a substantial part of KLIMAFORSK research is fundamental science and within the Norwegian scientific landscape other programmes were focused on the application of scientific knowledge towards creating technological solutions. This context should be considered when comparing the results to other research programmes focused on the green transition.

The bibliometric analysis indicates that on multiple indicators, KLIMAFORSK scores much higher than the world average. These indicators include the citation impact, policy uptake, news coverage and altmetrics (KLIMAFORSK publications by selected Norwegian researchers are likely to have been associated with greater levels of effort to increase awareness and online attention towards their findings). KLIMAFORSK scores lower than Horizon 2020 but still scores better than the world average. In terms of public-private cooperation, KLIMAFORSK clearly lagged behind Horizon 2020. These difficulties can be partially explained by the existence of other research programmes that fund less abstract scientific projects. Additionally, most impact was created within the climate modelling themes as opposed to the more applied topics of climate impact and climate adaptation. The uptake of R&I results has been on the agenda of KLIMAFORSK, but they have not been fully successful in implementing it.

17.6.3. Networking and infrastructure

One of the main reasons that KLIMAFORSK was founded was an evaluation of Norwegian climate research stemming from 2012. It concluded that Norwegian research activities on climate were of excellent quality and confirmed that Norwegian research groups were well-respected at a national and international level. However, the overall encompassing ecosystem lacked focus as most research groups worked independently. KLIMAFORSK was set up to help solve this lack of coordination. In that sense, KLIMAFORSK has fully served the networking efforts of the Norwegian climate community. Furthermore, there are excellent connections with international counterparts. While the publications are not as internationally focused (e.g. international co-publications) as H2020, this can be expected considering the size of the programme.

KLIMAFORSK placed high importance on communicating and disseminating the research (results). KLIMAFORSK facilitated the communication and dissemination efforts through multiple measures (e.g. communication requirements for calls and specific calls focused on communication and dissemination). KLIMAFORSK was generally successful with promoting the work within the scientific community, and contributing to network building within the climate research community. At the same time, it was less successful in transferring knowledge to other stakeholders.

17.6.4. Transdisciplinarity

In terms of KLIMAFORSK's transdisciplinarity, the evaluation committee found that KLIMAFORSK's efforts to be engaged in inter- and transdisciplinary activities were satisfactory. Through other sources, this was confirmed. While there was the intention to promote inter- and transdisciplinary activities, also through the FRIKLIM calls, in reality it was less successful as compared to what was hoped for. Partially this could be attributed to the fact that relatively little funding was allocated to these FRIKLIM call. In this perspective KLIMAFORSK was behind how Horizon 2020 tackled this issue. For this reason, one of the main recommendations made by the evaluation committee was to let inter- and transdisciplinary research take a prominent place in future climate research.

17.7. Conclusion

Our findings from by evaluation are presented below.

Effectiveness: Overall, the collected evidence shows that KLIMAFORSK can be regarded as an efficient programme. KLIMAFORSK's main objective of promoting outstanding climate research and providing knowledge about the connection between climate (research) and the benefits for society was realised. The topics covered by KLIMAFORSK help to showcase and develop the strengths of Norwegian climate researchers (e.g. climate modelling); they also cover a broad range of relevant topics (i.e. fundamental science questions and the impacts and adaptation measures). The research outputs by the Norwegian researchers are internationally well-regarded. The bibliometric analysis confirms this (both Norwegian H2020 publications and KLIMAFORSK recorded high scores much above world level on 1) the average of relative citations, 2) shares of highly cited publications 3) altmetrics).

KLIMAFORSK and the work of involved research groups have been vital for this and led to the strong contributions of Norwegian researchers to IPCC and other international fora.

However, there were some areas where the programme could have performed better: 1) in terms of the cross-disciplinarity (also confirmed by bibliometric analysis), and 2) the integration with the business sector/collaboration with industry (in this sense, KLIMAFORSK is lagging behind Horizon 2020).

Efficiency: Regarding the proportionality of costs to benefits of the research programme KLIMAFORSK, it can be said that KLIMAFORSK is an efficient research programme. With a moderate level of resources, KLIMAFORSK managed to produce excellent scientific output supporting a wide range of stakeholders.

In climate research, however, it is difficult to compare the costs to the benefits of the programme, as the benefits of climate research – especially for fundamental research – are often built on long-term observations. In addition to that, the research outcomes are often complex and difficult to explain. Even though dissemination of the results is part of the structural objectives (and this went well), dissemination to all relevant stakeholders remains a difficult task.

Nevertheless, interviewees indicated that, given the context, the KLIMAFORSK output was excellent. Also specifically with regards to cost-effectiveness, the organisational set-up (i.e. annual call with different themes) contributed to the efficiency as part of the process was standardised (in comparison, the free calls were considered less efficient).

Relevance: And, finally, given the high relevance (and evidence) of global climate change, KLIMAFORSK is a research programme that is highly relevant to both Norwegian society as well as the research community on a regional, national and global level. KLIMAFORSK aimed to include a wide variety of stakeholders, such as citizens and businesses, in the projects. Some topics included research that could be fed into local, regional or national policymaking, and some types of projects (collaborative projects) involving the users' community were required. KLIMAFORSK, therefore, aimed to fund research that is relevant to society. Our evidence shows that the use of research-based knowledge has increased as a result of KLIMAFORSK.

Furthermore, a few good practices were identified:

- The organizational set-up. There are three pre-determined themes (covering the fundamental research as well as climate change impacts and adaptation) that, on a rolling basis, have an annual call. Next to that, there is also a chance to apply for funding for more innovative projects (FRIKLIM call).

- KLIMAFORSK keeps its strategic priorities up-to-date through its programme board and through the annual discussions on research needs with the relevant policymakers. Annual evaluation of the focal point of the calls is helpful to keep the focus on the right topics.

- Aside from the scientific objectives, KLIMAFORSK also has the so-called structural objectives, which focus on a wide range of topics that all contribute to developing benefits in general and to society and the research community. Some of these objectives are integrated into the special calls and types of projects (e.g. collaborative projects and communication and dissemination projects).

- KLIMAFORSK has an important international aspect where international collaboration is promoted (e.g. joint international calls).

17.8. References

Research Council of Norway. (2012). Norwegian climate research - An evaluation. Research Council of Norway.

Research Council of Norway. (2012). Kunnskapsgrunnlag for en ny klimasatsing i Forskningsrådet 2012 (Knowledge base for a new climate initiative in the Research Council 2012). Research Council of Norway.

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17.9. Annexes

17.9.1. Guiding questions for stakeholder interviews

Greetings and acknowledgement of time.

Introduction by Technopolis Group.

– Could you introduce yourself, incl. your current position and your relationship with KLIMAFORSK?

– What could EU research funding in the field of climate change and adaptation learn from the KLIMAFORSK?

– We would like to ask you for your own and the evaluation committee's/organisation's perception of KLIMAFORSK´s performance over the past years?

– What effects /societal changes has KILIMAFORSK contributed to – and in what way (changed the understanding of climate challenges, new policies, changed behaviour, new synergies with other projects, etc.)

– Are you aware of the management's response to the main findings of the 2019 evaluation study?

– Can you reflect on the organisational set-up of the KLIMAFORSK programme (3-year cycle per topic; structural objectives)?

- What about your (KLIMAFORSK's) institutional perception regarding efficiency (in terms of funding objectives) and effectiveness (regarding overall programme delivery) ?

- Do you think that the KLIMAFORSKS has been delivering as expected in the area of climate change adaptation and green transition?

- What about the management of KLIMAFORSK? What has worked well, and what has been challenging?

- Do you have proposals for changes that enable KLIMAFORSK to be better adapted to challenges and research needs in the future? For example, changing priorities, etc

- Is there any identifiable strategy regarding the embedding of KLIMAFORSK within European /other international research funding programmes and objectives?

- How would you rate its relevance for Norway (scale 1 to 5)?

- Where would you see strengths/weaknesses of the KLIMAFORSK in terms of its embedding with the overall funding programme landscape in Norway… and in Europe? What would you need in order to foster both Norwegian climate-related research, as well as European linkages?

- Has KLIMAFORSK influenced national and international research priorities?

- What are the main solutions to support/enable/channel research follow-up into concrete transition measures?

- What do you believe to be required from the policy side to enable lasting green transition effects?

- What would be the KLIMAFORSKS's role in this process?

- In which ways is the KLIMAFORSKS replying to these challenges?

- Have the collaborative projects in the KLIMAFORSK portfolio, through requirements for user participation, contributed to ensuring that the research is relevant to the societal challenges?

- Do you think that the funds allocated through KLIMAFORSK could have been used in another way that would, to a greater extent, have contributed to outstanding research and relevant knowledge related to climate systems, effects and change?

- Is there anything else important (not covered yet) that you'd like to add (thoughts on what worked well and what has been challenging at KLIMAFORSK)?

17.9.2. Interviews

During the period May-August 2022, we conducted a series of 5 semi-structured online interviews with RCN, Norwegian Environment Agency (with a focus on policy changes), as well as with Steering Committee members and relevant scientific community members with KLIMAFORSK work experience. Each interview took roughly 60 to 90 minutes and followed a set of guiding questions for the different scenarios comprising public and private interlocutors. Our questions generally followed the idea of having our interviewees themselves assess KLIMAFORSK's strengths and success stories, in addition to its overall efficiency, effectiveness, and relevance.

We also aimed at capturing those socio-political obstacles which prevent the deeper structural changes necessary to bring about the "green transition" and the role of publicly funded science in this process. Strategies for better knowledge generation and, thus, public policy input were collected from our interviewees.

All interviews were transcribed and qualitatively analysed. The overall response rate was rather low. While the relevant Norwegian stakeholders were very much involved and helpful for the benchmark, the period during which the interviewing phase was planned covered the summer holiday period.

Many people we identified as potentially interesting to interview were not available for interviews for prolonged periods. Some interviewees preferred to remain anonymous with regard to their answers to our study.

Table 129. List of interviewees KLIMAFORSK.

Name	Role
Tora Aasland	Chair evaluation KLIMAFORSK
Anicke Brandt	Research Council Norway; Deputy advisor climate and environment, responsible for KLIMAFORSK – Research Council of Norway
Lena Cappelen Endresen	Head Climate team – Research Council of Norway
Øyvind Christophersen	The national focal point for the UN Climate Panel, chief engineer at the Norwegian Environment Agency.
Tore Furevik	Leader program plan committee and vice chair of the steering board for the 10 years climate program in Norwegian Research Council (KLIMAFORSK 2013-2017). Director Nansen Environmental and Remote Sensing Center and Adjunct professor at the Geophysical Institute, University of Bergen

18. Benchmarking 3: Benchmarking 3: FONA (Forschung für Nachhaltigkeit) – Research for Sustainability, Germany

Acronym	Meaning
BMBF	Federal Ministry of Education and Research
DDA	Multidisciplinarity Index
DDR	Interdisciplinarity Index
FONA	Forschung für Nachhaltigkeit
FP	Framework Programme
HTS	High-Tech Strategy
IPCC	UN International Panel on Climate Change
JPI	Joint Programming Initiatives
OA	Open Access
PROSYS	Earth-system Analysis and Risk Assessment

RTD	Research, Technology and Development
SDG	Sustainable Development Goals
SME	Small and Medium Enterprises

18.1. Summary

The FONA 1 and 2 framework programme (partly covering FONA 3) case study (Forschung für Nachhaltigkeit in German) is of specific interest for the international benchmarking whose aim is to identify lessons learnt from best practices worldwide supporting research and innovation and put in perspective the performance of the Framework Programmes in the area covered by the study.

In Phase I of the Green Transition Evaluation Study, the benchmarking exercise focuses on efficiency and effectiveness, as well as on relevance, and provides a predominantly qualitative comparative assessment of H2020, corroborated by bibliometric findings at country level comparison with the four international benchmarking cases which were selected in accordance with the Commission.

The Green Transition is the lens through which the evaluation exercise is regarded. The transition implies a strong connection to society. Therefore, the qualitative comparison of FONA with H2020 includes as dimensions of interest (a) the strategic development, which ought to reflect the adaptive capacity to react to a changing or emerging global situation, (b) the uptake of R&I results, and (c) networking and infrastructure. *Transdisciplinarity* serves as a fourth cross-cutting dimension.

According to the overall benchmarking exercise design in all areas covered, FONA fares exceptionally well (in particular, the volume of funding, strategic orientation and system properties) yet at lower levels of achievement than H2020, except transdisciplinarity. Both findings are owned by the different scopes of FONA 1 and 2, in particular, which had other output and engagement, including funding criteria. Overall, FONA contributed to establishing a sustainable interdisciplinary research network inside and outside traditional academic institutions. It expanded, according to contextual changes, over the years to incorporate policy-making, private and public sectors, and unlike H2020, successfully funded institutional, SME and research education transformation as well as large-scale infrastructure at the systemic level and from a broad, societal transformative point of view. With FONA 4, accordingly, this approach eventually emerged into a national strategy while evidencing some (as of yet) unmet structural and institutional challenges with regard to bringing about this broad transformation. These findings, however, have to do with political and institutional dimensions in times of multiple crises and cannot be addressed nor overcome by FONA itself.

18.2. Introduction and overview

18.2.1. Benchmarking approach

Typically, benchmarking involves the following steps, which we adapted for our international benchmarking pilot study: identification of problem areas; identification of similarities with similar interventions in the field; survey of measures and practices; implementation of new and improved practices. Learning and improvement are at the heart of a benchmarking exercise.

The acronym IDEAS captures the action steps of the benchmarking:

- **I**nquire: investigation of possible benchmarking areas
- **D**ecide: Selection of a relevant area
- **E**xpand: Exploration of key features of the area – causes, effects and solutions
- **A**nalyse: Seeking expert opinions
- **S**pecify: Interpretation of results for the way forward

In the case of the international benchmarking done in Phase 1 of the Green Transition Evaluation, which focuses on ex-post evaluating H2020, two evaluation criteria are key: **efficiency** and **effectiveness**. That said, in light of the Green Transition perspective and the paradigm shift that happened during H2020, **relevance** was added as an additional criterion of interest.

A pool of potential benchmark cases was determined by applying a set of selection criteria[1]. In accordance with the client, four international cases were chosen to be covered by the study (cf. Table 88).

International benchmarking cases selected for Phase I of the Green Transition Evaluation

International Benchmarking	Case	Country	EU	Beyond EU
Case I (pilot)	ACRP – Austrian Climate Research Programme	AT (Austria)	✓	
Case II	KLIMAFORSK	NO (Norway)		✓
Case III	FONA – Forschung für nachhaltige Entwicklung (*Research for sustainable development*)	DE (Germany)	✓	
CASE IV	NSF – National Science Foundation	US (United States of America)		✓

18.2.2. Methodology and case study structure

The FONA case study draws heavily on an ex-post-evaluation study assessment of FONA 1 and 2, and partially FONA 3, a series of expert interviews conducted in May/June 2022, and a quantitative study of FONA publication output up to 2019 (for bibliometric reasons of severely limited significance otherwise). Overall, the study scope has been to assess lessons learned and best practices from a long-standing national sustainability research program at the federal level of Germany, as well as to tease out valuable comparisons with H2020 (2014-2019).

Desk research: The multi-stakeholder evaluation study from 2020[1] on FONA 1 (2005-2009) and FONA 2 (2010-2014), partially covering FONA 3 (e.g. with regard to survey outcomes, funding and publication volumes), and other relevant documents. These encompass the online presence of FONA,[2] additional background and relevant policy papers about the executing project agencies and their mandate, funded projects, and beneficiaries.

1. **Identification of possible benchmarking areas**
2. **Internal reviews**, identification of interviewees à **Selection of relevant areas**: In the case of FONA, we decided to focus on those who conducted the 2020 evaluation of FONA 1 and 2, in addition to a leading scholar, both long-term involved in FONA and the relevant scientific community, as well as a few additional expert sources with some, although partial, expertise regarding FONAs track record and achievements.
3. **Data collection phase**: Interviews, focus groups, bibliometric data: We carried out a series of semi-structured interviews with four leading authors of the 2020 FONA evaluation study and with one expert scientific advisor and, previously, a beneficiary of FONA à **Expansion** with the aim of further identifying good (and bad) practices and understand causes and effects.

    1. All obtained qualitative data has been processed with the purpose of assessing both content and narrative framing – the way certain actors frame issues related to efficiency, effectivity and performance – in order to provide a comparable basis for comparison across benchmarking cases.
    2. The qualitative data were complemented by and interpreted in the light of the results of a quantitative analysis undertaken by Science-Metrix, and additional desk research à analysis involves expert opinions and quantitative data to complement further and increase the robustness of the objectives of the evaluation results.
4. **Dimensions for qualitative comparison with H2020**: given that the lens of the overall evaluation exercise is the *Green Transition*, which implies a strong connection to society, the following dimensions for the qualitative comparison with H2020 are foreseen:
    1. *strategic development*, adapting to changing/emerging global situations
    2. *uptake of R&I results*
    3. *networking and infrastructure*
    4. *transdisciplinarity* as a cross-cutting dimension

18.2.3. Study constraints

For this benchmarking pilot study, several relevant constraints had to be taken into account. First, due to the national and European internal political context at the time of sending interview requests, the German Ministry for Research did not permit conducting interviews with internal policy-makers and further staff concerned in the ministry's subdivision 72 with FONA. Second, an encompassing evaluation study of FONA 3 (2015-2019), which would have been most relevant for direct H2020 comparisons, has neither been mandated (currently in process) nor initiated yet. The only robust available data, however, only partially available for drawing conclusions on FONA 3 performance stems from the 2020 FONA evaluation study mentioned above. Third, FONA entails very limited program monitoring through its Profi-database hosted at the Ministry (point 1 mentioned above entailed that we had no direct access to the database for this study). That is, neither are encompassing statistical data collected on an annual basis nor are any other measures of progress made available publicly. This notwithstanding, the outcomes of the evaluation study 2020 with regard to FONA's overall performance provided us with **concrete entry points for our semi-structured interviews** with members of the evaluation study and top-profile members of the relevant scientific community.

We understand that given our overall theme of green transition and climate change adaptation/mitigation, a **focus on improving social impact through effective communication, differentiated objectives, and targeted instruments** is vital. Therefore, we focused during interviews on the highlighted improvement areas to pinpoint and identify lessons learnt and potential benchmarks for similar funding programmes in Europe.

Guiding questions for the interview of stakeholders as well as a list of interviewees are included in the annex.

18.3. Synthesis of evidence

18.3.1. Introduction to the international benchmarking case

FONA is the second in a series of four international benchmarking cases and, as such, builds on the ACRP (Austrian Climate Research Programme) pilot case.

FONA is under the auspices of the German Ministry of Education and Research (BMBF), more precisely, located with its subdivision 72 (FONA) within its division 7 ("Zukunftsvorsorge - Forschung für Grundlagen und nachhaltige Entwicklung", English: Care for the Future – Elementary Research and Sustainable Development). It emerged as an "out of the pipe" approach in 2005 and has since then continuously been developed into a systemic, interdisciplinary and transdisciplinary sustainability research programme, an objective which was boldly and positively achieved. FONA built upon the earlier Environmental Research and Technology program (1989-1994), aiming at including emission-poor production processes. In addition, in 1998, the "Umweltforschungsprogramm" (environmental research program) of 1997 expanded to include "socio-ecological research", at this time mostly referring to considering the full life cycle of products. Since then, the BMBF has established 13 focus points for selected economic sectors and, in parallel. Also, root cause analysis and ecosystem research gained track. Already at this time, the overarching objective has been to gain a better understanding of the complexity between human impact and natural processes, including the global dimension of environment and development.

In 2002, Germany adopted the National Strategy for Sustainable Development, which included two main motives: 1 PRONA (action-oriented sustainability concepts) and 2. PROSYS (earth-system analysis and risk assessment), overlooked by subdivision 72, sought to couple insights for the national strategy and its requirements. Overall societal resilience should be improved in the light of disruptive processes (e.g. climate change) but explicitly addressed also social security, environmentally-conscious globalization, societal integration, systemic risks avoided, food security and mega urban agglomerations put up on the agenda. These objectives and themes merged into FONA 1 2005, together with a strong inter and transdisciplinary concern.

According to the 2020 evaluation study, already early on, not only were knowledge and innovation generation targeted, but global challenges, including multi-stakeholder perspectives, have been addressed in concordance with German aspirations for European and global leadership. Similarly, FONA has additionally always been linked to the national high-tech strategies HTS I to HTS III and HTS 2025.

Institutionally, FONA has been steadily and consciously taken as a tool for not only establishing a proper position division within the BMBF – i.e. which would have enabled sustainability concerns to become a transversal issue across all German RTD activities – thus also aiming at countering the fragmentation into several divisions, referates and, as a side product, thematic silos. FONA should additionally foster research from subdivision 72 (divided into 5 "Referate" or thematic secretariats) and thereby connect the innovation ecosystem of economy, politics and society in novel ways. Today, FONA is still essentially linked to subdivision 72 and contributes to its attempt to boldly connect the innovation ecosystems, in particular since the establishment of the FONA Strategy (by end-2020).

18.3.2. FONA background

FONA is one of the BMBF's main funding programmes and is deeply committed to the 17 SDGs, the national and European climate targets until 2030, as well as establishing sustainability discourse and action, including change with regard to institutional, governance, teaching/research and higher education landscapes, thus by default going beyond the goals of H2020's R&I scope. The following three key areas have been developed for the organically further developed FONA Strategy (adopted 2020), in itself drawing upon FONA 1 to FONA 3:

- Achieving climate targets
- Protecting, exploring and using Resources and living environments
- Further developing society and economy – fostering well-being in the country

All three areas have assigned 8 thematic action fields respectively, each including 25 concrete actions, which very roughly compare to Work Programmes and different research instruments (CSE, RIA, IA, etc.) in H2020.

Since its beginning, funding and support for research in sustainability has not only been defined thematically but also structurally: across disciplines and including all stakeholders across sectors of society to achieve better systemic understanding. The international impact is important, including cooperation with developing and BRICS-T countries.

Research should be useable in practice and therefore present useful outcomes, the latter not only in terms of technologies but also as knowledge and behaviour recommendations for political and public planning processes. Moreover, being relevant for societal and technological uptake, i.e., similar to H2020, they should address societal challenges. In particular, five structural properties sought to be fostered: transdisciplinarity, internationalization, transfer orientation and systemic perspectives.

FONA's total funding volume (F1 to F3 or 2005 to 2018) has been **5.198.942.641** €, funding **9773** projects in total. Its overall budget, including own costs: 5.851.736.165 €; Own costs amounting to roughly one 1/8th or 0,125% of the overall budget.

18.3.3. Legal basis and governance

Generally, in Germany, the legal basis for overall public spending and financing is provided by the annual §23 *Veranschlagungen* (roughly translated as "calculations") and §44 Public Spending Permissions ("*Bewilligung*"), as well as the "*Bundeshaushaltsordnung*" (BHO) and its subsequent relevant public administration prescriptions (*Ausführungs- bzw. Verwaltungsvorschriften* (VV-BHO). The overall provision of public funding is stipulated in the annual budgets and subject to previously accorded achievement and delivery negotiations. This system builds the basis for FONA funding and for funding of concrete instruments, actions and projects according to FONA-managed procedures, which in turn, on the side of FONA-funded beneficiaries, are partly regulated by the tax and subsidy benefit-related law of 2019 (FZulG; BGBl I S. 2763). In terms of public administration and budgeting, FONA is embedded within the German High-Tech Strategy 2025 (HTS), which also includes other research funding programmes administered by other German ministries.

FONA's programme owner is the Ministry of Education and Research. However, on the basis of regular public tenders, operations are continuously handed over to executive agencies (*Projektträger*). Executive agencies are responsible for the day-to-day handling of project proposals, reviews, funding administration, etc., but do not have any mandate for project monitoring. While shifting executive agencies constitutes a long-standing regular German practice, problems arise with continuously building up institutional memory and, in particular, implementing a coherent set of monitoring standards.

18.3.4. Thematic Orientation of FONA

FONA is a multi-program initiative that can be thematically and call-relatedly divided into three periods. However, funding periods, project lifetimes (which could be extended) and outcomes do not necessarily relate to the three overarching FONA periods. The 2020 evaluation divides them in the following way: F1: 2004-2009; F2 2010-2014; F3 2015-2018. In addition, as of 2019, the renamed FONA Strategy is underway. All FONA programmes included funding for the following areas:

- Climate research
- Energy research
- Research on Biodiversity
- Marine and Polar Research

However, every program call puts emphases differently. FONA 3, for instance, included three flagship initiatives: Green Economy, City of the Future, and The Energiewende (Germany's transformation of its energy system). In transdisciplinary terms, FONA 3 focused on the following "fields of prevention research" for sustainability:

- Maintaining and enhancing quality of life and competitiveness
- Using resources intelligently and efficiently
- Protecting common assets: climate, biodiversity and the ocean
- Education and research: working together for a sustainable future

In addition, FONA aims to transform environmental and sustainability education by directly modifying higher education curricula across *Länder* and local administrations. To foster social and not only technological innovation, research and education went hand in hand. This includes a focus on climate impact research, disaster risk mitigation and adaptation, vulnerability analyses, sector-specific approaches, locally relevant sustainability research on potentials and transformations, etc. While F1 and F2 were essentially geared towards establishing a relevant inter and transdisciplinary scientific community, F3 saw the opening up towards all disciplines and the private sector, including large-scale production companies.

From the vantage point of viewing itself as a European leader in sustainability research, FONA 3 explicitly aimed at close collaboration with H2020's climate action calls and within KICs, such as the one on raw materials and the Climate KIC initiative. These activities should foster the R&I triangle between education, research and industry in "order to transform R&D results into marketable products and services more swiftly and efficiently".[1]

A particular focus also lies on marine and polar research collaboration – including the acquisition of the research vessel "Sonne" in 2013/2014 through FONA 2 – e.g. within the European Marine Strategy Framework Directive, but also OSPAR COM and HELCOM.

FONA 3 also participated with the Joint Programming Initiatives (JPI), JPI Water, JPI Climate and JPI Ocean.

While FONA is the largest research programme of its kind in Germany, it is by far not the only one addressing sustainability. Funding programmes located with the Federal Ministry for Economic Affairs and Climate Action address politically much more sensitive strategic sectors with regard to high tech, automotive industries and energy.

18.3.5. FONA target group and funding shares

The programme targets different kinds of research organisations and science-oriented organisations, but also NGOs, public administrations and the private sector more broadly. Research disciplines include, among others, natural sciences, social and economic sciences, and legal and technical topics that usually have to be solved in interdisciplinary and, in many cases, also in transdisciplinary ways. Additionally, FONA serves to acquire novel research infrastructure (including large-scale) as well as transform existing infrastructures.

Project partners are not limited to German research institutions and can include foreign researchers as well as businesses and other practitioners as long as full publication of results is guaranteed. Across FONA 1 to 3, research institutions in Germany outside traditional academia have been the biggest beneficiaries in the field of infrastructure, yet in total (projects and proposals), universities have received the highest shares (46% of all funding instruments and 36% of proposals funded). External research organizations (e.g., Fraunhofer, Helmholtz Association, Leibniz, Max-Planck, etc.) received 36% of all funding subsidies and 28% of proposals were funded.

However, in terms of overall FONA budget share, external research organizations received 44% (largest share), of which the four largest (mentioned above) allocated 71%. Environmental research organizations without ties to universities and the four largest external institutions outside academia only received 3,8% of the overall funding budget; 1,3% received commissioned research by the BMBF.

18.3.6. Previous evaluations and lessons learned

FONA has been evaluated at the national level in 2020 (covering a work time period of 2018-2020); the accompanying research for FONA 3 has been tendered in 2022 tendered. The 2020 evaluation study, most valuable for this benchmarking exercise, built on a complex set of cases studies, a large-scale survey across 8251 FONA-beneficiary project heads (principal investigators, PI) and a Sounding Board. This board included 6 representatives from academia, companies, public administration, NGOS and has been consulted for individual interviews and workshops. Additionally, 3 focus groups were carried out on 1. Interdisciplinarity, 2. Transdisciplinarity; and 3. Transfer pathways to economy with up to 9 participants each.

The 2020 evaluation underlined **positive achievements**:

a) FONA effectively helped set up or expand/reorient new research institutions through which sustainability research as such has been successfully established. Additionally, this way created, career paths were fostered (occasionally over several projects and years).

b) Project and publishing activity has been increasingly transdisciplinary, co-authored with numerous international partners, as well as the establishment of new research directions (e.g., socioecological). This is owed to an in-built preoccupation with global environmental problems, justifying a global role of responsibility for German funding and engagement.

c) FONA targeted and managed to achieve a good number of PhD awards, in addition to funding young career research groups (at an early stage), which added qualification impulses for employment and labor markets.

e) Companies, particularly small and medium, benefitted from FONA with a number of novel innovation potentials, improved market position, and further qualification of researching staff. There were also positive effects according to revenue and employment and internationalization.

f) New forms of evidence-driven public engagement were developed (across citizens, municipalities, civil society). Municipal administrations were fostered as to effectively uptake innovative solutions and ideas.

g) FONAs overall governance structure is very reliable and in persona of some leading figures within the subdivision 72 have been leading FONA since 2005 or even during its precursory programs.

h) FONA has demonstrated flexibility and community participation to include shifting contexts, to grow and to adapt its portfolio, particularly between FONA 1 and 2, on the one hand, and FONA 3 and 4, on the other.

The same evaluation study finds some serious **caveats** to these outlined successes, and in particular were confirmed through, interviews with lead authors of the study.

For instance, with regard to e), it became clear that on the mid to long run; only larger companies can maintain a sustained benefit from these advances, posterior to the end of FONA-specific support programmes. This notwithstanding, it is relevant to mention that SMEs had a larger share of benefits during the FONA-support phase, for instance, fostered innovation power, improved market position, and qualification of the research staff.

With regard to a) and c), young inter and transdisciplinary scholars did not find the same resonance with labor markets (in and outside academia), which means that lasting establishment of scholarly careers in inter and transdisciplinary research remains an intricate challenge.

Furthermore, is the governance of FONA with regard to g) and h) somewhat hampered by not including proper programme monitoring, and also rudimentarily compiling project (abstract) and outcome data in the Ministry’s profi data base. According to some interviewees, full project and funding disclosure, transparency and openness on the beneficiaries, etc. would not be interest of all parts (including FONA beneficiaries), as well as current legal frameworks.

Representatives from the scientific community also claimed to much weight by non-academic members in FONA’s advisory board of experts (in particular after FONA 3).

Generally, the 2020 evaluation study’s main findings listed the following research and societal improvements as recommendations for the next years without spelling out priorities:

- **Structuration and differentiation of funding instruments:** according to elementary research, applied research and R&D research with a clear marketization perspective.
- **Like the transition from H2020 to Horizon Europe, the adoption of a mission-based approach:** target-operationalization towards societal challenges, cross-sectorial by nature as to FONA acquiring a pioneer role for the BMBF. **Relevant for impactful missions would be** extensive interdependency fine-tuning, ambitious and inspiring but realistic and measurable targets, as well as openness to diverse solution pathways. R&D&I policy needs to become fundamental part of societal change, including institutional and budgetary changes.
- **Digitalization should be fostered,** especially for fostering research communication and long-term availability of results, not only to foster impact but also with regard to its relevance for sustainability as such

- **Funding of social innovation from and within civil society, with a particular focus on upscaling**, including measures for applicants at different career stages and reviewers from outside traditional academic settings.
- **Establishment of experimental spaces:** Living labs for social innovation, bottom-up explorations, research and public administrations should be funded without a targeted marketization interest but long-term perspective (approx. 10 years).
- **Create dedicated databases and platforms for transformative knowledge**, including new taxonomies, providing clear orientation in the light of multiple crises and required disruptive transformations (energy, traffic, food, etc.), but also for the identification of success factors and best practices, as well as the upscaling from niche success to mainstream application. This includes the exit from certain technology, energy and production processes.
- **A necessary institutionalization of research processes-related reflection (including quality criteria) for inter- and transdisciplinary research.** This relates to the distinction between the transformative and transdisciplinary role of science but also to science impact and the quality of science more broadly.
- **Transfer perspectives should be explored and expanded from the vantage point of innovation systems.** From the very start, already at the level of designing funding impulses and pillars, economic and juridical dimensions need to be taken into account, and policy-wise addressed, when exploring sustainable transformation practices. As an integral part, the innovation context must be considered and funding instruments, seen as “learning programs” continuously be fostered and therefore flexibly adapted.

At the **operational** level, the following recommendations were highlighted:

- **Project teams should receive support means for enhancing transdisciplinarity**. In addition, the criteria for transdisciplinarity should receive more attention in the selection process. Also, transdisciplinary project management tools should be promoted.
- A better **support** for **identifying and selecting project partners** is required, particularly to foster inter and transdisciplinarity. Targeted funding of networks and structures between science and private/public sector could be one way forward, in addition to massively enhancing science promotion and dissemination.
- Proposal and review process needs clear **definitions** and criteria for (according to differentiated and specific calls) interdisciplinarity, transdisciplinarity, marketization/employability and systemic perspectives. Project selection including **oral presentations**, in addition on-paper review processes, should be promoted.
- Improving **monitoring** and public disclosure of outcomes
- Consider Strategic use of real-time **secondary assessments**

18.3.7. Relevance

Arguably, according to international policy recommendations (IPCC, EU Green Deal, etc.), the overarching objective of climate and climate impact research is, beyond data collection and periodic updates thereof, to effectively and concretely contribute to the green transition, the achievement of the Sustainable Development Goals (SDGs) and, in the case of Germany, to fulfilling the German Climate Action Program 2030.

In this sense, FONA and its funding pillars are uniquely positioned by combining and working across the public, private, and research sector. To this contributes its clear global outlook of concern with research focuses on the Polar Regions and oceans, but also the developing world.

According to our interviews, and this has been confirmed across all our interviewed stakeholders, in its early years FONA has however had a “branding issue”, with rather low levels of recognisability in and outside academia. This had also to do with quite a closed group of researchers and institutions benefitting, in some institutional and departmental cases even “existentially”, from FONA funding (FONA 1 and 2). While this gradually been remedied, it is not a program open to everyone and everywhere from the civil society (having its own difficulties in terms of organisation, decision-making, etc.), explicitly NGOs, and the social care sector, with most of its funding going to non-academic (higher) research institutions and in particular to the 4 major non-academic research organizations active at the national level. A trend to centralization and established scholars, despite attempts otherwise to foster PhD and postdoc scholars, thus cannot be dismissed.

In terms of policy uptake, the FONA evaluation study finds a slight budget allocation (1,3%) to directly mandated research from the BMBF. However, according to our interviews, FONA has not been conceived as policy advisory program, and therefore the knowledge and information path has not frequently been from research to society and back to policy-making (except at the local, e.g., municipal level). In other words, FONA was less focused on, e.g., delivering results for steering nationally relevant climate policies in new directions, rather than inciting and impacting in society, higher education and private sectors to implement interdisciplinarily relevant knowledge and discourses with regard to sustainability and climate change mitigation/adaption (as of FONA 3 and 4).

There is also another dimension of unmet relevance which needs to be discussed: while FONA has effectively managed to establish and foster a relevant scientific community, there is a gap perceived by interviewed experts with regard to better implementation and embedding of FONA perspectives and outcomes as a cross-cutting issue between larger national international funding programmes. On the other hand, FONA has provided for instance tsunami-warning systems to Indonesia, contributes to ocean science through the SONNE vessel, etc. at the global level, thus evidencing a clear understanding of climate change as something of global concern. Several of our interlocutors confirmed that international partnerships within FONA-funded projects were expanding over time. This can be corroborated by bibliometric findings: A share of 80% of H2020 publications were international co-publications, against 58% for FONA publications by selected German authors (notwithstanding the methodological difficulties of such comparison). The increase over time in international co-publication was driven primarily by increased collaboration with Associated countries. The share of publications with a least one participation by a researcher from an Associated Country went from 8% in FONA publications to 27% in H2020 publications for selected German authors. Average share of authorship for authors from Associated countries has gone from 1% to 5%. Also, participation by researchers from RIS countries has also increased for German researchers when comparing their H2020-funded papers against FONA-funded ones.

This certainly reflects diverging policy priorities interests between the European and national funding level. FONA understands itself as leading European sustainability framework programme, in this sense facilitating comparisons with H2020 and Horizon Europe, at least with regard to the German research landscape. Also, within universities, large-scale EU-funded research with an extremely competitive positive approval rate, are highly resources-binding during the proposal preparation phase and thus frequently perceived as unnecessarily binding staff and resources with highly uncertain outcome. To some extent, FONA can do better at the local and national level, especially if it includes novel research (e.g., reflexive and exploratory) spaces as highlighted in the 2020 evolution's recommendations.

In the sense of bringing about a green transition, and taking into account societal and policy relevance as the necessary fields for generating lasting chance, we argue that the EU FPs, but also other member states, could learn quite a lot from the German long-standing efforts in the field. Vice versa, Horizon Europe with its already implemented mission-based and society challenges-focused approach could provide a blue print for further developing FONA 4 (and perhaps beyond) in the future. Additionally, efforts to harmonize and align national and European funding (through partnerships, JPIs, etc.) should be fostered even further. In all cases, this would involve a much better, public transparent monitoring and knowledge-transfer mechanism for FONA, for instance, in order to achieve full socio-political relevance and thus increased media attention.

18.3.8. Effectiveness

Sustainability research (FONA 1 and 2) and sustainability transformation research funding (esp. FONA 3 and 4) by the subdivision 72 was an effective way to reach the goals that FONA FP strived to accomplish. There is impact on multiple levels: internationally, nationally, regionally, and locally. This can be exemplified by FONA action contributions to the IPCC and COPs at the international level, the FONA action on a national level and research on climate impact adaptation (e.g., droughts, floods, etc.) on a regional or local ecosystem level.

The focus of the framework program, now strategy (FONA 4), is to provide various instruments for placing sustainability talk and actions on the national and institutional agenda, including the private sector. It does not limit itself to the national context, but includes a global outlook, while focusing on systemic institutional, capacity and knowledge transformation at the national level. Inter- and transdisciplinary vulnerability studies, risk management approaches and, to a lesser extent, policy analysis are key actions in this undertaking.

Cross-disciplinarity

With regard to the 2020 evaluation assessment of FONA our bibliometric analysis comparing German H2020 funded publications with FONA funded ones, evidences important nuances: Considering only the capacity of each funder to foster large shares of highly multidisciplinary publications within sets of supported articles (DDA10%), a statistically robust gap was found for H2020 funding as compared to FONA funding. H2020-supported publications by selected German authors were 20% more likely to be highly multidisciplinary (1.2) than expected, against 70% more likely than expected (1.7) for FONA-supported papers. However, when looking at interdisciplinarity, according to Science Metrix data, H2020 and FONA-funded publications performed similarly in both tests, or with inconclusive, small differences (DDR of 0.7 to 0.8 in the main test, although statistically inconclusive).

Academic-private co-publication

What additionally seem to have achieved rather little output impact is the stated relevant FONA focus on including and financing non-academic research and private sector research: A share of 13% of H2020 publications by selected German authors included both academic and private firm authors, against 4% for FONA publications. The value-added of H2020 funding on this dimension was statistically definitive at +9.4 percentage points. It can be noted that H2020-funded publications generally saw more academic-private co-publications (16%) than FONA-funded publications (6%), reinforcing the conclusion that H2020-funding has been more effective at fostering academic-private co-publication than FONA funding.

Beyond academic publication output, it is, however, notable that, according to our expert interviews, FONA 1 and FONA 2 actions produced many reports and other text output that contributed to policy-making but also mainstreaming sustainability research and transformation in Germany. Regarding this point, preliminary bibliometric data, however preliminary, supports FONA effectivity when compared to H2020: The normalized share of publications by selected German authors cited in policy-related documents was twelve times the expected for both their H2020 and FONA publications. H2020 funding did not so far enable differential gains on this dimension against FONA funding.[1]

Overall, FONA 1 (still limited to establishing funding and networking bases for socio-ecologically likeminded scholars in the climate research field) and FONA 2, effectively managed to expand and reorienting both in the academic and private sector (particularly with FONA 3). Companies, especially SMEs, benefitted from FONA with a lot of innovation potentials, improved market position, and qualification of researching staff. According to the 2020 evaluation report, there are also positive effects according to revenue and employment and internationalization. However, according to our interviews, and despite a higher effectiveness curve for SMEs during FONA-supported actions, only larger companies were able to maintain a sustained benefit from these advances once finalised FONA-specific support.

Gender Equality in publication authorship

In this regard, H2020 publications by selected German researchers included at least one female author in 89% of cases, against 76% of FONA publications, resulting in clear signal of differential effectiveness for H2020 funding in the controlled analysis. The clear signal just described was not retrieved in the overall H2020 and FONA publication sets, however. Authorships on H2020 publications were taken up by women in 31% of cases on average, against 31% of cases for FONA publications. H2020’s differential gap is significant here at -5.6 percentage points. Again, the signal from the controlled analysis is not repeated in the overall publication sets for average shares of authorship taken up by women. Both H2020 and FONA publications recorded averages of 30% of authorship taken up by women.

In the public domain, new forms of engagement were developed and municipal administrations were provided with evidence-based data as to effectively uptake innovative solutions and ideas. This has been the case thanks to high applicability relevance of FONA funded research. However, transdisciplinary research and outcome require a higher level of coordination and communication tasks, which also affects the way transition action support needs to be conceived in terms of efficiency.

Propensity to open-access publishing

A proportion of 95% of H2020 publications by selected German researchers were available under an OA modality, against 91% of FONA publications. H2020's slight lead was not statistically robust, meaning it would be safer to assume that H2020 and FONA funding have both fostered comparable levels of OA publishing.

18.3.9. Efficiency

Overall, project administration and the proposed management of FONA have been esteemed as highly transparent, professional and efficient. FONA has existed for over 20 years and is a large framework programme with extensive experience in funding research, which has resulted in continuously optimised and standardised processes. The supporting IT systems, except refined tools for project monitoring, are generally well-developed, but access to the "Profi database" requires specific authorization from the Ministry and is not accessible to the general public (unlike CORDIS). As they are integrated into the streamlined project application, selection and funding allocation processes, they work as they are expected to deliver.

In terms of the actual application process for proposals including the merit review criteria which are all clear and well-explained in documentation. However, it should be noted that interviewees mentioned that a program USP and ownership problem persisted throughout FONA 1 and 2, in the sense that it was not always clear to everyone involved in the projects that FONA has been the main funding source for institutional and research activities. This improved over time, as well as more explicitly addressing civil society organizations and policy-makers, clearly demonstrating flexibility and learning effects from programme to programme.

As mentioned above, transdisciplinary research – effectively required to bring about a green transition at all societal levels – comes with certain strings attached. These refer, on the one hand, to increased coordination and communication demands, which bloat project management and tend to expand project cycles substantially, especially when including stakeholders from outside traditional research. In the case of FONA, awareness about this growing gap has been created but still awaits a coordinated response – according to our expert interviewees from the academic research community.

In addition, scaling up knowledge and network creation through mutual learning exercises and twinning projects was hampered to some degree (in FONA 1 and 2) by not (much) including NGOs and other social and environmental civil society organisations, or civil society more broadly. In order to bring about more disruptive and radical solutions to the triple crisis (nature, biodiversity, climate change impact), this would be necessary.

However, structural and historically grown institutional organization in the field of higher research and education is lacking behind these demands: predominantly, academic career paths still follow a single or dual disciplinary approach, and same holds for higher education as well, where, however, multidisciplinary and interdisciplinary focuses have increased. Yet, there is still leeway to fully incorporating transdisciplinary research in its broad sense through co-design, co-creation and two-way knowledge transfer.

According to our interviewees, FONA 3 aimed at addressing some of these shortcomings by providing additional action to academic institutional transition, yet it struggled to ensure further employability and success of this way built-up scholars' careers (and institutes) beyond FONA funding.

With regard to H2020, there might be some similarities if we look at broad cross-cutting calls and related research action. With regard to Horizon Europe, there is a risk of establishing some sort of

“European inter and transdisciplinary research community” which might struggle to obtain relevant posts and research funding beyond the European FPs.

These critical remarks notwithstanding, FONA 1-3 effectively managed to, and was confirmed across all interviewed sector representatives, deliver what it was supposed to deliver. That is, an **interdisciplinary research community**, an **international outlook with a claim to European and world leadership in the field of climate change adaptation**, with successful ties to the private and public sector (especially at the regional and municipal level); and eventually also **sustainability-related impact within academic research structures**, including addressing **direct institutional transformation** (both within universities and non-academic research institutions) with dedicated funding instruments (in this sense going beyond EU FP’s typically indirect approach).

18.4. Short comparative analysis

The international benchmarking foresees a short qualitative comparative analysis of the study case with H2020. FONA represents the second case study (the first after the ACRP pilot case) and the synthesized 2020 evaluation effort is still ongoing, the results for the overall comparison are not available yet – they are expected to be ready in late autumn 2022, and will be provided in an overall comparison across all benchmarking cases. However, the ACRP pilot already established four cross-cutting evaluation dimensions which should be addressed in all benchmarking cases.

18.4.1. Strategic development

In terms of strategic development, the key question is whether the programme kept abreast with and adapted to changing or emerging global and national situations, such as the Paris Climate Accords or the Green Deal. In this regard, FONA fares quite well according to our interviewees – its intent has been to provide scientific background for the implementation of German Climate Action Programme 2030, the European Green Deal, the 17 SDGs, and the Paris Agreement in Germany. In particular, the shift from FONA 2 to FONA 3 towards a more encompassing national research programme, re-potentiated with FONA 4 (FONA Strategy) evidences this strategic reasoning and purpose. There are however critical voices, which pointed out the persistent lack of civil society and NGO engagement, which with FONA 3 was addressed, and should have been fully integrated with FONA 4 seems to have been improved (yet, evaluation results are missing).

While efforts towards the Green Transition have not been scaled up – in relative terms – by FONA like they have within H2020 (through the Green Deal), the former has indeed reacted to the shifting policy landscape. Although FONA highly stimulates interdisciplinary research, it could be argued that it does not go far enough to foster lasting and sustainable transdisciplinary research to establish and deep connections to societal actors.

18.4.2. Uptake of R&I results

Within the FONA-operating ministry, uptake has continuously occurred since FONA 1, however concrete data on this process is scarce. In our study it has been pointed out (as of yet) missed transformation of subdivision 72 into a cross-sectoral secretariat or similar, which would have meant to make sustainability an overarching issue for all Ministry actions and programs.

However, FONA results and actions were taken up by the academic and private sector; The 2020 evaluation dedicated a case study to SME’s take-ups which seemed very positive, but also evidences certain challenges with prolonged follow-up engagement after funding expires due to economic barriers.

Identification of concrete action fields for the FONA program is mostly an internal process within the ministry. Hence, some detachment to other societal sectors cannot be dismissed: While FONA has occasionally included funding of explorative research, there are very few funding instruments in place for improving the precise identification of concrete problems between decision-makers, civil society and the scientific community, to which further research should reply to. In addition, FONA is today much more geared towards socio-ecological research for technological and economic applicability than it used to be in the beginning. So-called “synthetizing” social science approaches, focused on stakeholder mapping, decision making support, and making governance processes more inclusive and effective, have been a rather weak point throughout all FONA programmes.

Regarding corroborating data on patent citation uptake (which are very preliminary and subject to change), it was found that H2020 publications by selected German authors have already received citations from patents (10% less than expected at 0.9), whereas FONA publications by the same authors have not. It should be noted that mentions of journal publications in patents is optimally computed using citation windows of 7 years, which have not elapsed here.

In more statistically robust terms, H2020 publications by selected German authors, mentioned at least once in online journalistic coverage, was six times the expected level, against three times the expected level for the share of FONA publications by the same authors. The lead by H2020 publications on this dimension was statistically robust, and comparison of the base-lines also reinforced this finding. The share of H2020 publications mentioned at least once in a Facebook post was three times the expected level, against 50% above the expected level for FONA publications by the same authors. Again, the H2020 lead was statistically robust here, although external validity of these findings may be somewhat limited as shown by the two baseline findings.

18.4.3. Networking and infrastructure

In terms of network, FONA 1 and 2 have undoubtedly played a vital role in establishing not only research and outreach actions, but also institutional change at the national and regional level, particularly within academia. For instance, the renowned IASS (Institute for Transformative Sustainability Research) in Potsdam has received funding through FONA from early on.

While FONA 1 and 2 focused on an emerging socio-ecologically minded interdisciplinary research network, with FONA 3 (and in the context of political changes at the ministerial level) opted for more pro-growth and pro-industry engagement, effectively broadening FONA’s scope and instruments. FONA 4 turned into a national strategy, with as of yet unclear results.

In terms of infrastructure for transformative sustainability engagement, FONA contributed from the beginning by enabling the updating and acquisition of the required and appropriate large-scale equipment for universities and research institutions outside academia through public procurement, which would have not been possible otherwise (e.g., research vessel “Sonne” in FONA 2).

Internal (institutional and governmental) policy uptake of FONA results could have contributed more to set the agenda across ministries, though, especially with regard to impacting, e.g., with sustainability criteria, the research actions and funding by the concerned ministries for high-tech and industries. This, however, would be linked to broader public engagement, political participation, fostered dissemination as well as programme monitoring – that is, in all fields were FONA 1-3 has been regarded as high potential but with an average performance.

18.4.4. Transdisciplinarity – Conclusions

In terms of transdisciplinarity, FONA 1 and 2 clearly lagged behind by focusing on interdisciplinarity by default, i.e., not having a broader engagement in its scope. Also, FONA 3 partly and in certain actions – by including the private sector – managed to incorporate both policy-making and civil society more broadly (and certainly more than comparable other framework programmes in Germany). For this reason, in the following, we present some overall comparison results regarding the benchmarking of FONA against H2020, which corroborate this statement:

- H2020 publication performances for selected German authors were at a clear led to FONA achievements on the dimensions of 1) share of highly interdisciplinary publications 2) share of academic-private co-publications; and 3) balanced citation impact as captured by the CDI 4) Field-weighted CiteScore (journal-level citation impact) 5) altmetrics mentions in online journalistic coverage 6) altmetrics mentions on Facebook posts.
- H2020 publication performances for selected German authors were at a clear led to FONA achievements, but potentially with limited external validity, on the dimensions of 1) share of publications written as international co-publications 2) average number of distinct countries of affiliation per publication 3) Shares of publication with authorship contributions from at least

one woman researcher (although this achievement did not carry over to average publication-level share of authorships by women).

- Both H2020 publications and FONA publications recorded comparable scores on 1) average multidisciplinarity and average interdisciplinarity 2) share of publications available in OA 3) uptake in policy-related literature 4) Twitter and Wikipedia mentions.
- FONA publications by selected German researchers performed better than H2020 publications by the same researchers on 1) shares of highly multidisciplinary publications.

18.5. Conclusions

18.5.1. Efficiency

In terms of efficiency, FONA framework programme fares relatively well: given its scope and learning curve, it managed to process an increasingly large number of projects quite efficiently and even managed to grow and expand over the course of several years, e. g. with regard to launching the new FONA Strategy as encompassing funding mechanism. Furthermore, certain solutions to the persistent criticism of different stakeholders to structural problems were found, e.g., the lack of a proper monitoring system or the missing digitalization strategy. However, project review and selection function, according to all experts interviewed, to an extremely professional and transparent level, as well as the overall portfolio administration. Since there are structural limits in terms of validity and robustness of bibliometric data, several statistical comparisons on the outcome efficiency need to be considered carefully. In addition, at least FONA 1 and parts of FONA 2 focused on producing different outcomes (e.g., conferences, working papers, reports, discussion inputs, policy briefs, etc.) than high-impact scholarly journal articles. Overall, FONA's efficiency can be assessed as very high.

18.5.2. Effectiveness

Overall, for the assessed time period (excluding FONA 4; and FONA 3 partly) the collected evidence shows that the broad field of sustainability research and actions (including climate) that is funded through FONA is an effective means to accomplish the FONA objectives. FONA plays an essential role in research, knowledge, capacity-making and institutional transformation that is conducted on multiple levels, ranging from international to local research. FONA objectives had therefore to adapt and expand over the years, evidencing a high level of flexibility and responsiveness to changed societal and political contexts.

With regards to the impact of the research that was funded by FONA, German H2020 publications tend to achieve a stronger citation impact profile, as well as scoring well on other indicators such as policy uptake, patents, communication, and dissemination activities, but numbers for German FONA publications are certainly high and way above world levels.

18.6. Annexes

18.6.1. Guiding questions for stakeholder interviews

1. What could EU research funding in the field of climate and adaption learn from the FONA?
2. We would like to ask you about the identified strength/weaknesses regarding FONA's performance over the years, especially in the light of its socio-political objectives (e. g. raising climate change awareness)?
3. Can you identify some of the most relevant success stories?
4. Is FONA engaged in its own benchmarking exercises of other comparable funding programmes in the field (Switzerland, Norway, etc)?
5. What has been the management response to the main findings of the 2020 evaluation study?
6. What are the strategic links between FONA and other ministry actions in the field?
7. How is follow-up of results and uptake – also beyond the Ministry – ensured?
8. What do you believe to be required from the policy and research side to enable lasting green transition effects?
9. What has been FONA's role in this process? And what have been differences between FONA 1-3?
10. Do other governmental or academic stakeholders have a voice in defining FONA's overall strategies, goals and/or selection of research funding?
11. To which extent is the Ministry included in these tasks and its voice given weight?
12. What about your evaluating perception regarding efficiency (in terms of funding objectives) and effectiveness (regarding overall programme delivery)?

13. Is there any identifiable strategy regarding the embedding of FONA within European research funding programmes and objectives?
14. Where would you see strengths/weaknesses of FONA in terms of its embedding with the overall funding programme landscape in Germany…
15. .. in Europe?
16. What would you need in order to foster both German climate related research, as well as European linkages?
17. In the ministry, who is in charge of the overall strategy?

18.6.2. FONA Interviews and list of interviewees

During June and July 2022, we conducted a series of 5 semi-structured online interviews with FONA evaluators and scientific community members who have also been acting on the FONA, Sounding Board. Each interview took roughly 45 to 90 minutes and followed a set of guiding questions for the different scenarios comprising public and private interlocutors. Our questions generally followed the idea of having our interviewees themselves assess FONA's strength and success stories, in addition to its overall efficiency, effectiveness, and relevance.

We also aimed at capturing those socio-political obstacles which prevent the deeper structural changes necessary to bring about the "green transition" and the role of publicly funded science in this process. Strategies for better knowledge generation and, thus, public policy input were collected from our interviewees.

All interviews were recorded, transcribed, and qualitatively analysed. The overall response rate was very positive, taking into account the extreme time pressure of this pilot study; some interviewees preferred to remain anonymous with regard to their answers to our study.

Table 130. List of FONA-related interviewees.

Senior Expert	Lead FONA evaluator PROGNOS
Senior Expert	FONA evaluator PROGNOS
Lead evaluator	Fraunhofer ISI
Professor	Scientific Director, IASS Potsdam
Senior Expert	Fraunhofer ISI

[1] It should be noted that mentions of journal publications in policy-related documents are optimally computed using citation windows of 4 years, which have not been elapsed in the available. Therefore, these findings are preliminary and subject to change.
[1] https://www.fona.de/medien/pdf/pdf_8rch1v/bmbf_fona3_2016_englisch_barrierefrei.pdf, p.30.
[1] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccp/2020/BMBF_FONA_Evaluation_Abschlussbericht_2020.pdf; https://www.prognos.com/sites/default/files/2021-01/bmbf_fona_evaluation_abschlussbericht_2020.pdf
[2] https://www.fona.de/en/
[1] objectives and scope of the case; target groups; budget; governance; type of R&I targeted; policies and instruments; positioning at national/regional and international level; organisation; implementation processes; identification and tackling of state-of-art scientific, technological, and/or socio-economic problems; SDG orientation; monitoring and evaluation of performance

19. Benchmarking 4: National Science Foundation, United States research programme

19.1. Summary

The NSF (National Science Foundation) is of specific interest for the international benchmarking (in the Framework of Evaluation of Green Growth aspects within Horizon 2020), which aims to identify lessons learnt from best practices worldwide supporting research and innovation and put in perspective the performance of the Framework Programmes covered by the study.

In Phase I, the benchmarking exercise will focus on efficiency and effectiveness, as well as on relevance, and provide a qualitative comparative assessment of H2020 with the four international benchmarking cases which were selected in accordance with the Commission. The NSF (National Science Foundation) was selected as one of the two from countries beyond EU borders (one larger and another one –smaller) for the international benchmarking studies. Next to that, the availability of information also played a role in the selection. NSF is, thus, representing the selection of a larger country (USA) outside the EU.

The Green Transition is the lens through which the evaluation exercise is regarded. The transition implies a strong connection to society. Therefore, the qualitative comparison with H2020 foresees as dimensions of interest (a) the strategic development, which ought to reflect the adaptive capacity to react to a changing or emerging global situation, (b) the uptake of R&I results, and (c) networking and infrastructure. Transdisciplinarity (d) serves as a fourth cross-cutting dimension.

In all areas covered NSF fares quite well; the research activities provide a good output in multiple areas such as scientific impact, multidisciplinary and policy uptake. In terms of crossdisciplinarity, selected NSF researchers' publications tended to be above world level. In terms of integrating multiple perspectives in all of NSF's activities, the NSF aims to have a broad representation within the organization, its portfolio, and other activities. Furthermore, through the application of knowledge or methods from other disciplines not only climate research progresses, but also the progress of science in those other disciplines is promoted (e.g. the combination of Big Data and AI in climate research). Still, it has to be noted that our benchmarking results show that the NSF has not matched the levels of achievement of H2020 in the different dimensions of comparison. Nevertheless, it was observed that collaborating with and learning from the European counterpart allowed NSA to make significant progress. The political landscape was important external factor (that has influenced the progress of the science). For example, during the benchmarking period not all research could be conducted as some topics were deemed as too politically sensitive; and there were budgetary cuts that led to gaps in long-term observations.

This report is a mere snapshot, though, as the comparison with H2020 requires the synthesis results of parallel, ongoing evaluation efforts within the Green Transition Evaluation. Still, it is prepared to absorb those results as soon as they become available and presently captures the key results of the study on the NSF case, including quantitative results that showcase the NSF in terms of scholarly output.

19.2. Introduction and overview

19.2.1. Benchmarking approach

Typically, benchmarking involves the following steps, which we adapted for our international benchmarking pilot study: identification of problem areas; identification of similarities with competitors in the field; survey of measures and practices; implementation of new and improved practices. Learning and improvement are at the heart of a benchmarking exercise.

The acronym IDEAS captures the action steps of benchmarking:

- **I**nquire: investigation of possible benchmarking areas
- **D**ecide: Selection of a relevant area
- **E**xpand: Exploration of key features of the area – causes, effects, and solutions
- **A**nalyse: Seeking expert opinions

- **S**pecify: Interpretation of results for the way forward

Proper benchmarking needs to define the areas, baselines, and criteria according to which the benchmarked entity will be assessed. In our case, two criteria are highlighted as of primordial relevance: **efficiency** and **effectiveness**. In addition, we hold that relevance, coherence, and impact (the most difficult to access) are likewise relevant to gain an encompassing estimation of the overall performance and process.

19.2.2. Objectives of the international benchmarking

Overall, the aim is to assess the performance, understood as long-term processes, of NSF in the light of its encompassing policy environment. This means assessing best practices for achieving real impact, ideally positive change, at the level of municipalities, policy-making at the level of the concerned ministry, and/or, the relevant research community, which NSF expressly seeks to enhance, deepen, and foster at the national level, and, in a second step, between the national level and its ties to international partners, institutions, and networks.

19.2.3. Methodology and case study structure

The methodology for our international benchmarking case NSF comprises the following methods:

- **Desk research**: evaluation studies of previous years (if available), online presence of NSF, additional background and relevant policy and strategic papers about the NSF and the U.S. Global Change Research Program, funded projects and beneficiaries.
  - Identification of possible benchmarking areas
- **Internal review:** identification of interviewees and **selection of relevant areas**: In the case of NSF, we decided to focus on researchers, advisory committee members and NSF staff members, policymakers and programme and board managers, with the assumption that they would provide most relevant views.
- **Data collection phase**: Interviews, bibliometric data: We carried out a series of interviews with the above mentioned interviewees with the aim of further identifying good (and bad) practices and understand causes and effects.
  - All obtained qualitative data will be processed with the purpose for assessing both content and narrative framing – the way certain actors frame issues related to efficiency, effectiveness and performance – to provide a comparable basis for comparison across benchmarking cases.
  - The qualitative data were complemented by and interpreted in light of the results of a quantitative analysis undertaken by Science-Metrix and additional desk research. The analysis involves expert opinions and quantitative data to complement further and increase the robustness of the objectives of the evaluation results.
- **Analysis:** Analysis of the collected data to assess the scores for NSF in the following areas:
  - Effectiveness = level of smooth achievement of the NSF's own goals, objectives and purposes
  - Efficiency = value for money in terms of wider societal and policy impact (research output as an intermediary step)
  - Impact = Research output of NSF funding
  - Relevance = relevance attributed by the external analysts (ourselves) to the NSF program pillars, according to their respective objectives and purposes, in addition to impact and coherence.

19.2.4. Study constraints

For this international benchmarking exercise, several constraints were to be taken into account:

1. Availability of data. Due to the fact that the NSF funds research into all science and engineering disciplines, relatively few (evaluation) reports specifically tailored to research into the green transition were available.
2. Availability of people to be interviewed: Few people, both from inside the NSF as well as outside, such as researchers, agreed to be interviewed. Among the reasons that were mentioned were their own availability, their perceived unfamiliarity with H2020 or their reluctance to some extent to assess the NSF as a whole.

Overall, the data available are considered sufficient for the purpose of analysis. Guiding questions for the interview of stakeholders as well as a list of interviewees are included in the annex. In addition, we conducted an in-depth analysis of the material and (rather rudimentary) research project database available online.

19.3. Synthesis of evidence

19.3.1. Introduction to the international benchmarking case NSF

In the United States of America, one of the main funders of fundamental research is the National Science Foundation (NSF). The NSF is an independent agency of the United States Federal government. It focuses on basic science and funds in a bottom-up manner. It was founded when in 1950, the United States Congress passed the National Science Foundation Act. The specific objectives of the NSF were to:

- promote the progress of science;
- advance the national health, prosperity, and welfare;
- secure the national defence.[162]

The NSF offers a unique approach as compared to the European system and mindset. Focussing on a few sub-divisions for the benchmark, such as "emerging frontiers", "chemical, bioengineering, environmental and transport systems", "environmental research and education", and "geo-sciences", is expected to yield competitive benchmarking results. In the context of transformative research, further issues to learn from NSF relate to scientific bias and the handling of low-risk tolerance associated with constrained funding.

19.3.2. NSF background

The NSF has a comprehensive, overarching mandate to help keep all the fields and disciplines of science and engineering research healthy and strong. The NSF accomplishes this through programmes that support basic research that is conducted by individual researchers or collaborative groups of investigators. The objectives of the NSF on the one hand serve the ambitions to let the US research community advance the scientific frontier and subsequent economic benefits, while on the other hand also contributing to addressing important societal challenges, such as climate change, that the US already is or might be facing in the future.

The annual budget of the NSF is more than $7 billion (ranging from $7.2 billion in fiscal year 2014 to $7.5 billion in fiscal year 2017). This funding covers around 25% of basic research conducted by US colleges and universities that is supported by the federal government. Annually, there are about 50,000 requests for funding, and there is an acceptance rate of 20-25%. Whether a request for funding gets awarded depends on two criteria that the NSF uses. The first criterium is intellectual merit, which is based on how well a request can contribute to the scientific frontier. The second criterium is broader impacts, which includes how well a request can potentially achieve positive societal outcomes and to what extent it helps to tackle specific societal needs.

In the United States there are multiple stakeholders that are involved in and fund research into climate (change), aside from the National Science Foundation. The United States Global Change Research

[162] https://www.nsf.gov/about/

Program is an overarching programme that aims to bring together different Federal agencies and support synergies between the funding activities of all distinct Federal agencies (see box "The U.S. Global Change Research Program" below).[163] The United States Global Change Research Program is an important stakeholder for climate research in the US.

Box 4. The U.S. Global Change Research Program

In order to streamline and coordinate the activities of all US stakeholders the United States Global Change Research Program (USGCRP) was founded in 1990. There are thirteen United States Federal agencies that take part in the USGCRP:

Department of Agriculture; Department of Commerce; Department of Defense; Department of Energy; Department of Health and Human Services; Department of the Interior; Department of State; Department of Transportation; Environmental Protection Agency; National Aeronautics and Space Administration; National Science Foundation; Smithsonian Institution; and the U.S. Agency for International Development.

The USGCRP was founded to study climate change and other related environmental changes that might have an impact on the United States and its economic and societal well-being. The research that is conducted by the Federal agencies that are part of the USGCRP includes basic research, applied research, communication activities and policy advice.

The USGCRP follows the outline that the decadal Strategic Plan sets out. For instance, the "*National Global Change Research Plan 2012–2021: A Strategic Plan for the U.S. Global Change Research Program*" was the blueprint for the strategy that was followed between 2012-2021. Each three years the new context for the USGCRP and the progress that has been made is touched upon in a *triennial updates*-publication. This *Triennial update* also highlights new developments that the USGCRP will consider in the remaining years from the decadal Strategic Plan

The existence of the USGCRP is important to consider in the context of this benchmark. Not only because it highlights that the NSF is one of the thirteen Federal agencies that fund research into climate (change), but also because to some extent it dictates the context in which the NSF operates. While the NSF is an independent Federal agency, general strategic directions also partially affect the research topics that NSF will fund.

Another important consideration for the context of this benchmark is the political landscape during the period of the benchmarking exercise.[164] A major and influential decision prior to the period of the benchmark is the 2007 decision of the Supreme Court in the case Massachusetts v. EPA, in which was found that the EPA was authorised to regulate GHG emissions, such as CO2 from motor vehicles as air pollutants under the Clean Air Act. This meant that the EPA could regulate the emission standards from different industries when GHG endanger public health or welfare. During the Obama administration, President Obama published the President's Climate Action Plan in 2013.[165] In this plan there was a specific chapter "Using Sound Science to Manage Climate Impacts", with a special focus on supporting research into climate (change). In 2015, President Obama accepted the Paris Agreement.166 Therefore, when the Paris Agreement entered into force the United States became a Party. We therefore can deduct that climate change research was high on the agenda for the Obama administration. This however changed when the Republicans won control of the Senate during the 2014 midterm elections. The trend to focus less on climate (research) continued under the Trump administration. For instance, in 2017 the United States withdrew from the Paris Agreement. President Trump also proposed to have the budgets cut for Federal Agencies that fund climate science on multiple occasions, especially for the funds for climate science. Furthermore, the Trump Administration

[163] National Coordination Office (NCO) for the USGCRP. (2012). THE NATIONAL GLOBAL CHANGE RESEARCH PLAN 2012–2021: A strategic plan for the U.S. Global Change Research Program
[164] Congressional Research Service. (2021). U.S. Climate Change Policy. Retrieved from: https://crsreports.congress.gov/product/details?prodcode=R46947
[165] https://obamawhitehouse.archives.gov/president-obama-climate-action-plan
[166] United Nations Treaty Collection, Chapter XXVII: Environment, "7.d. Paris Agreement," December 12, 2015, https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-a&chapter=27&clang=_en. U.S. depositary notification C.N.10.2021.

directed Federal Agencies to eliminate one-third of their advisory committees.167 This meant that multiple agencies researching climate (change) had to deal with decreased budgets or reduced their activities in anticipation of the budget cuts. However, not in all cases did Congress agree with the proposed budget cuts for Federal Agencies.[168]

19.3.3. Thematic orientation of NSF

The NSF has a mandate to support all fundamental science and engineering in the United States, except for medical sciences. This is also reflected in the organisational structure of the NSF. The NSF is divided into the following seven directorates:

- Biological Sciences;
- Computer and Information Science and Engineering;
- Engineering;
- Geosciences;
- Mathematical and Physical Sciences;
- Social, Behavioural, and Economic Sciences; and
- Education and Human Resources.

Each of the directorates are headed by an assistant director and each is further subdivided into divisions like materials research, ocean sciences, or behavioural and cognitive sciences.

In addition to that, the NSF also focuses on interdisciplinary activities, through for instance the Office of Integrative Activities, the Division Emerging Frontiers and Multidisciplinary Activities, or the Environmental Research and Education group.

19.3.4. NSF target group

The NSF funds individual scientific investigators or collaborative groups of scientific investigators.

19.3.5. Legal basis and governance

The National Science Foundation is an independent federal agency created in 1950 by Congress through the National Science Foundation Act. While acknowledging that there is no ideal way to determine a priori which research proposals will yield transformative results, NSF aims to ensure that its funding programs have review practices that help identify those proposals that are highly innovative. As previously mentioned, this is based on the two merit review criteria intellectual merit and broader impacts.

19.3.6. Instruments

The process of applying for research funds is highly standardised at the NSF. The process consists of three phases. The first phase, which has a length of 90 days, includes the announcement of the call and the proposal submission. The opportunities are published on the NSF website as well as Grants.gov. The applicant should upload the finished proposal to NSF via the NSF FastLane System. If the proposal satisfies the NSF requirements, it will be sent for review. If not, the proposal may be returned to make the proposal satisfy the requirements.

The second phase covers the proposal review and processing of the review. First, the reviewers are selected based on their specific or broad knowledge of the topic in scope. The review itself will look at

[167] https://www.federalregister.gov/documents/2019/06/19/2019-13175/evaluating-and-improving-the-utility-of-federal-advisory-committees
[168] Nature. (2019). Trump proposes slashing science spending at the NSF. Retrieved from: https://www.nature.com/articles/d41586-019-00851-1

two criteria: Intellectual Merit and Broader Impact. There are scientific, programmatic and technical reviews. The phase continues with a recommendation of a programme officer to the Division Director. This Division Director decides whether to continue the application process or not. This phase may take up to six months.

The third phase, which may take up to thirty days, covers a review process that looks at the business, financial and policy implications of funding the application. Finally, a proposal gets awarded funding.

In addition to funding research through core disciplinary programmes, NSF also provides support for facilities, equipment, instrumentation, centres of research, and activities such as workshops that help to advance fields of science. Most of the proposals funded by NSF also support the development of the science and engineering workforce.

NSF also explicitly calls for potentially transformative proposals to help ensure that NSF and the research community maintain a focus on the frontiers of science and engineering.

19.3.7. NSF Objectives

The NSF objectives are 1. to promote the progress of science, 2. to advance the national health, prosperity, and welfare, and 3. to secure the national defence.

The NSF is the only federal agency mandated to support all non-medical fields of fundamental research into science and engineering. The NSF operationalises its objectives through an ongoing but frequently shifting series of thematically different programmes, some of which relate to the thematic areas of this evaluation exercise.

In the United States, the Government Performance and Results Act (GPRA) (Public Law 103-62) requires Federal agencies, such as the NSF, to develop strategic plans that set out the strategy, goals, and means to achieve those goals and to ensure the effectiveness of the agencies. During the period that is covered by this benchmark, several NSF strategic plans were developed and published:

- Empowering the nation through discovery and innovation: NSF strategic plan For Fiscal years (FY) 2011-2016
- Investing in Science, Engineering, and Education for the Nation’s Future NSF Strategic Plan for 2014 – 2018
- Building the Future: Investing in Discovery and Innovation. NSF Strategic Plan for Fiscal Years (FY) 2018-2022

Aside from the mission and visions of the coming years for the NSF, these strategic plans also set out the strategic goals and core values of the NSF. The strategic goals reflect the NSF objectives and are also aimed at making the NSF effective and efficient. This can be exemplified by the 2014-2018 NSF Strategic Plan, where the strategic goals are the following: Transform the frontiers of science and engineering; Stimulate innovation and address societal needs through research and education; and Excel as a Federal Science Agency. While at the core, these strategic goals stay the same, in newer versions of the Strategic Plans, the goals are adjusted to the newer context in which the NSF operates.

The core values encompass how the NSF should always work. In every decision that is made, these values should be considered. In the 2018-2022 Strategic Plan, the following values were included (in brackets is a brief explanation): Excellence (with regards to science), Public Services (role in society), Learning (support staff), Inclusion (representative of the broader community), Collaboration (focus on teamwork), Integrity (highest standards of ethical behaviour) and Transparency. For each of the subsequent Strategic Plans, the core values were adjusted and added according to the needs at the time. It can be observed that the core values have become more explicit over the years.

19.3.8. Previous evaluations and lessons learned

We could not find any relevant evaluation reports, and interviewees indicated that such reports do not exist.

19.4. NSF Benchmarking results

19.4.1. NSF Benchmarking results

The NSF has objectives to improve the progress of science and promote the nation's health, welfare, and prosperity, and help to safeguard national security and defence. The research funded by the NSF that focuses on climate (change) is in line with the general NSF objectives. Increasingly novel methods, tools and knowledge are used to model climate change and which impact climate change has on society.

The NSF is a Federal Agency that funds fundamental research in all science and engineering fields and disciplines, not only research into climate change. It has extensive experience as a funding agency. Consequently, the processes for calls for proposals, applications, reviews, and grant awarding are highly standardized. Interviewees indicated that this is one of the features of NSF research funding that is regarded as pleasant. Especially compared to funding processes at other agencies, where reading the calls take a long time, the standardized format allows researchers to not spend an excessive amount of time on identifying potentially interesting call for proposals.

Research that is supported by NSF funding is used by policymakers at different levels of the government. For instance, the NSF, through the USGCRP, has contributed to multiple National Climate Assessments (NCA) – reports that cover climate research in the US in a holistic way, from the findings of climate modelling to more applied research that looks at the effects of climate change on agriculture and human health and welfare. The NCA is published every four years. Additionally, NSF also contributes to the IPCC. Interviewees also indicated that at lower government levels, data and research were used for policymaking or strategic planning.

Due to the many scientific fields and disciplines that are covered by the NSF, the NSF is in a great position to fund multidisciplinary projects and bring together different stakeholders that are normally separated by the boundaries of their distinct disciplines. The NSF is aware of this unique position as a funder of a broad range of science and engineering disciplines. There are divisions and advisory committees focused on bringing together distinct scientific fields. For instance, there is the Office of Integrative Activities which plays a coordinating and leading role in programs which require input from multiple Directorates or new interdisciplinary scientific and engineering concepts. An example of such a multidisciplinary program is the Coastlines and People Hubs for Research and Broadening Participation (CoPe)-program, which is aimed at studying the interactions between nature and human ecosystems in coastal areas.[169] This CoPe program is also a good example of research that is truly relevant at the regional or local level. Similarly, there is an opportunity to submit proposals that are transdisciplinary and have high risk but also a high potential to transform science, namely through the Research Advanced by Interdisciplinary Science and Engineering (RAISE) proposal. There are, therefore, multiple ways through which NSF aims to broaden the scope of research activities.

Because NSF climate research activities are heavily integrated with and influenced by the USGCRP, it is important to understand that context as well. During the benchmarking period, the National Global Change Research Plan (2012–2021) was published – a decadal strategic plan for the USGCRP. The plan highlighted how the past two decades focused on observations, process research, and modelling of the physical climate system. Looking at the future, the Program felt poised to integrate important dimensions more fully to the understanding of the Earth system by incorporating complex and critical components such as the roles of ecosystems and human communities. To this end, the Program identified four strategic goals:

- integrate the physical, chemical, biological, and social sciences
- interact with decision-makers about research results relevant to their needs
- Advanced communication and interdisciplinary education in global change research
- make effective use of assessment results to inform future research activities.

Funding multidisciplinary research was/is one of the focal points for future USGCRP research and, therefore, also for NSF-funded research. Especially the interaction between climate and humans has

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[169] https://beta.nsf.gov/funding/opportunities/coastlines-and-people-hubs-research-and-broadening-participation-cope

become an important topic (as exemplified by the CoPe program). While it has been on the top of the agenda, the execution of it has been lacking to some extent. In addition to creating synergies by combining different scientific fields, an important policy of the NSF is also to promote diversity and inclusiveness, which also encourages the integration of different perspectives into research. It also exemplifies the shift from only modelling climate change towards investigating the implications for local communities that are or will be affected by climate change. A 2021 report by the National Academies of Sciences, Engineering and Medicine confirms that in the future, the NSF should aim to create an integrated initiative that covers all disciplines that are related to modelling the Earth's system.[170] One of the interviewees mentioned that during the beginning of the benchmarking period, Horizon 2020 was ahead of the NSF with regard to finding the interface between the natural and human world. However, by collaborating and learning from the European counterpart, large steps have been made. It isn't easy to discern whether and to what extent this shift started during the benchmarking period or afterwards.

Another notable example of the position of the NSF to support groundbreaking research is the National Ecological Observatory Network (NEON). NEON is a nationwide research infrastructure through which terrestrial, aquatic, and atmospheric ecosystems are monitored over an extended period using remote sensing instruments. The data that is generated through this observation facility can be used for many different purposes and scientific disciplines.

Beyond the four strategic goals mentioned by the decadal (strategic) plan of the USGCRP, the USGCRP is also committed to improving its assessment of decision-maker's needs. This translates to providing stakeholders with timely and relevant information. To this end, the Program is committed to implementing a long-term, consistent, and ongoing process for evaluating global change risks and opportunities. This is exemplified by the previously mentioned research outcomes (e.g. NCAs, etc.). Lastly, the Program also recognised the need to communicate beyond immediate stakeholders and reinforce communication with the public through education and engagement in the Program's core research activities. In its triennial 2016 update, the USGCRP more markedly highlights the urgent need to communicate the links between what it calls "climate-related global change" and human livelihoods. It also displays how it has advanced the four identified strategic goals. One example of this is *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (2016).

As the NSF is one of the thirteen Federal agencies that make up the USGCRP, it means that the USGCRP's goals and agenda-setting strategies are likely to have a meaningful impact on the NSF's own goals and agenda. Looking at the NSF Strategic Plan (2018-2022), the link between the two is clear. The NSF identified three strategic goals:

- expand knowledge in science, engineering, and learning
- advance the capability of the United States to meet current and future challenges
- enhance NSF's performance of its mission

The first goal identified by the NSF can be seen as a conducive objective to the first goal identified by the USGCRP. The USGCRP aims to integrate the main scientific fields with the social sciences, while the NSF aims to expand knowledge in the main scientific fields. The second goal identified by the NSF also has strong links to the second goal identified by the USGCRP. The USGCRP aims to provide relevant research to decision-makers to help them make informed decisions. In tandem, the NSF aims to help the United States to advance national health, prosperity, and welfare; to secure the national defence. Lastly, the NSF identified an additional "agency priority goal" aimed at expanding public and private partnerships to enhance the impact of NSF's investments and contribute to American economic competitiveness and security. Within this last goal, the NSF aims to expand its connection with industry, foundations, and philanthropies to maximize the scientific, economic, and societal impacts of its investments. In this last goal, there is an echo of the USGCRP overall aim of having broader communication with the public to make more public the Program's core research activities.

In two previous NSF Strategic Plans, communication and dissemination efforts are also mentioned; however, the NSF Strategic Plan (2018-2022) clearly stresses the role of making results and

[170] https://www.nationalacademies.org/news/2021/09/national-science-foundation-should-create-next-generation-earth-systems-science-initiative-new-report-says

knowledge widely available to the public. According to the plan, the NSF intends to use new means to communicate and improve the availability and access to data.

Regarding the organizational set-up of the NSF, the merit review criteria that are used by the committees deciding on whether to award funding to a proposal are noticeably clear. The focus of the criteria is to select the best proposal and fund the best research. While interviewees indicated that this, in principle, is good, the criteria are initially difficult to understand. Furthermore, interviewees indicated that sometimes it leads to not funding creative, innovative calls because they do not fit into the existing mould. The same holds true for proposals from underrepresented communities. However, it should be noted that the NSF places high importance on diversity & inclusion (D&I). Another aspect of the proposal review process is how reviewers are selected. First, reviewers are selected based on their (general or specific) knowledge of the science and engineering disciplines or other qualities that support their expertise. However, what is interesting is that proposers can suggest reviewers for their proposals.

Another aspect of the organisational set-up of the NSF is the advisory committees. All Directorates and Offices have external advisory committees composed of external experts that bi-annually provide feedback and advice. The topics that are covered are recommendations on the management, the balance of the programme and future directions of research. One of the interviewees mentioned that the members of the advisory committees also contribute to white papers on the future of research in their respective scientific fields.

Interviewees also indicated that the NSF is a lenient partner in terms of how one can spend the funding once it has received the grant award. At some other funding organisations, it is set in stone when Principal Investigators (PIs) will receive money throughout the project period. The NSF is more flexible in that regard, as they acknowledge that different projects have different funding needs. Interviewees indicated that when getting funded by the NSF, there is room to discuss this and that it is not a problem to have an uneven disbursement schedule. The same holds true for time extensions of projects that are already funded.

The turnover of program managers or directors can, in some cases, be relatively high. This has its advantages and disadvantages. While it discourages favouritism, it also means that, in some cases, there is little continuity. This means that over the course of a funded project, there can be multiple program directors, which reduces the advantages long-term relationships can bring.

As explained before, the political landscape during the benchmarking period cannot be ignored, as there were profound changes during the period. Another consequence was that, according to interviewees, over the benchmarking period, researchers often found new funding streams, including from corporate partners as well as philanthropists, to diversify funding sources. This also reflects the effects of the political influence in the united states, as during the Trump administration, less focus was put on research into climate (change).

19.4.2. Quantitative benchmarking of NSF

The following quantitative benchmark of NSF was prepared by Science-Metrix. It compares NSF and H2020 with each other and to world averages from several perspectives: International co-publication output; cross-disciplinary research; science-industry co-publications; science-industry co-publications; citation impact; gender equality in authorships; open access; policy-related uptake; and indicators beyond academia.

Science-Metrix identified a subset of US researchers in Scopus that had contributed to both NSF-funded publications and H2020 publications.171 NSF publications metadata were retrieved from the NSF Public Access Repository and then filtered for thematic alignment with green transition topics. A total of 603 H2020 publications with contributions from these US researchers and a total of 2,758 NSF-supported publications with contributions from the same set of authors. These two publication sets were mutually exclusive; that is, publications with both H2020 and NSF funding were excluded from the analysis.172 Below, only statistically robust findings have been retained in the key findings.

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[171] It should be noted that Science-Metrix could not determine whether these researchers had been directly attributed funding as part of these two programmes, or whether they had simply contributed to publications supported by these programmes through the contributions of other authors.

[172] All results presented below are point estimates derived from a bootstrapping procedure aimed at measuring margins of errors. These results are complemented by 95% stability intervals that allow an assessment of how statistically definitive results are. Statistically definitive results should be reproduced in a future comparison between H2020 and NSF based on similar datasets to the one used here, all things being equal.

19.4.2.1. International co-publication profiles

A share of 99% of H2020 publications was international co-publications, against 60% for NSF publications by selected US authors.173 A proportion of 61% of H2020 publications were written by at least one EU27 researcher as either the first, last or corresponding author, against 12% in NSF publications. The share of publications rises to 79% when considering the EU27+UK aggregate, capturing the many collaboration linkages between the US and the UK.

A proportion of 57% of H2020 publications by selected US authors were international co-publications with contributions from an author from a Third Country as either the first, last or corresponding author. This share was about the same in NSF papers by the same authors. H2020-supported collaborations do not appear to broker higher collaboration figures with other Third Countries for participating US authors, although this finding could also capture stability in the distribution of key authorship roles between US authors instead.

The average number of unique countries per publication in H2020 publications was always above the corresponding figures found in NSF publications for selected US authors at statistically robust levels.

The thematic baseline figures show that H2020 publications with US authors that are also NSF funded do tend to be much more collaborative than either baseline (2.2 countries per paper on average for H2020 publications in general, 1.7 countries per paper on average in NSF publications).

While differential increases in unique EU27 and ERA countries involved in international co-publications were expected, H2020 publications by US researchers also saw increases in the average number of involvement by Third Countries (from 2.0 to 2.5 unique countries on average per paper). The combination of these observations is that, on average, H2020 publications by US researchers recorded authorship from 6.3 distinct countries on average, whereas this figure was 3.0 for NSF publications by the same US authors.

19.4.2.2. Cross-disciplinarity

Selected US researchers' publications tended to be above the world level in terms of multidisciplinarity174 in their NSF publications, but these scores dropped to the world level in their H2020-supported publications. The resulting differential decreases were statistically robust.

Selected US researchers' multidisciplinarity in their NSF-funded publications was higher than the NSF baseline (1.4 to 1.2 on DDA), but US researcher's multidisciplinarity in their H2020-funded publications was lower than the H2020 baseline (1.1 to 1.2 on DDA)

US researchers' publications tended to be on the world level on the interdisciplinarity indicator (average of the relative diversity of disciplines in the references of a given publication - DDR), at 1.0 or 0.9. H2020-publications recorded similar levels of interdisciplinarity.

Both H2020- and NSF- funded publications by selected US researchers saw slightly less interdisciplinarity than the corresponding baseline figures, indicating that the selected set of researchers tends to conduct less interdisciplinary research than other H2020 and NSF-funded researchers.

19.4.2.3. Academic-private co-publication

A share of 22% of H2020 publications by selected US authors included both academic and private firm authors, against 13% for NSF publications. The added value of H2020 funding on this dimension was statistically definitive at +8.5 percentage points.

It can be noted that H2020-funded publications saw more academic-private co-publications (16%) than NSF-funded publications (7%), reinforcing the conclusion that H2020-funding has been more effective at fostering academic-private co-publication NSF funding.

[173] It should be kept in mind that the US is a Third Country with regards to participation in H2020 projects. Any participation in H2020 projects or publications therefore increases its share of co-publications with EU27 researchers by definition.
[174] Average of the relative diversity of disciplines in the research backgrounds of different authors of a given publication - DDA indicators

19.4.2.4. Gender equality in publication authorship

H2020 publications included at least one female author in 78% of cases, against 76% of NSF publications, resulting in roughly equivalent performances.

Authorships on H2020 publications were taken up by women in 22% of cases on average, against 26% of cases for NSF publications. H2020's differential gap is significant here.

The comparisons between the baseline figures do not converge with the comparisons above and therefore indicate that the analysis based on selected US authors may be of low representativeness for the whole of H2020 and NSF.

19.4.2.5. Citation impact profiles

Note that only about 59% of NSF publications and 47% of H2020 publications in the analysis here had been published in 2019 or before and, therefore, could be included in the citation impact assessment.

Except for the journal-based citation indicator (FWCS), H2020 publications by selected US authors perform much above their NSF-funded counterparts on all citation impact indicators at statistically robust levels. These differential increases build on already very strong citation impact profiles. In short, H2020-funding to selected US authors takes already world-leading groups of researchers in terms of scientific excellence and allows them to reach truly exceptional citation achievements.

The H2020 score on the citation distribution index (CDI) was much above that of the NSF publications (42 against 33; remember that the world level on this specific indicator is set at 0, and the maximum score is bound at 50). The CDI indicator is a particularly robust citation indicator that considers performances by all papers in a given publication set, whereas other citation impact indicators can sometimes reflect exceptionally high performances by outliers.

More than the majority of publications (69%) issued by H2020 projects with participation from selected US authors fell amongst the top decile of publications most cited for their year and subfield (HCP10%). No less than 20% of publications issued by H2020 projects with participation from selected US authors reached the status of exceptionally highly cited publication within their subfield and year, within the top centile (HCP1%).

In light of these strong findings, it should be repeated that they apply only to the subset of selected US authors that participate in both H2020- and NSF-funded projects. These findings may not inform about the differential performance of H2020 funding for its core European population of researchers against the achievements of NSF funding for its mainly-US-based population of researchers.

The comparison of H2020 to NSF thematic baselines can help disentangle the general effects of H2020 funding versus effects that are found specifically for selected US researchers. For citation impact indicators driven by highly cited publications (ARC, HCP10%, HCP5% and HCP1%), H2020 and NSF thematic baselines recorded similar achievements, indicating that the differential gain recorded in favour of H2020 funding was not representative of H2020 funding outcomes outside the selected set of US researchers.

On the CDI, however, there is a positive differential for the H2020 baseline versus the NSF baseline (24 to 20) that converges, although with a smaller magnitude, with the effect found for selected US researchers. It, therefore, appears that H2020 green transition funding has been more effective than NSF green transition funding on balanced citation impact performances of supported researchers.

19.4.2.6. A propensity towards open-access publishing

A proportion of 93% of H2020 publications by selected US researchers was available under an OA modality, against 84% of NSF publications (data not shown). H2020's lead was statistically robust.

19.4.2.7. *Policy-related uptake*

The normalized share of publications by selected US authors cited in policy-related documents was six times the expected for both their H2020 and NSF publications. H2020 funding did not enable differential gains on this dimension against NSF funding.[175]

The comparison of policy-related uptake between the H2020 and NSF baselines diverges from the result above, adding concerns about external validity to the limitations already reported above.

19.4.2.8. *Citations in patents*

Citation windows for uptake of peer-reviewed publications in patents are often set at seven years or more, an interval that has not yet elapsed for the H2020 and NSF publications considered here. Findings should therefore be interpreted with much caution and are likely to change in future assessments. Nevertheless, it was found that NSF publications by selected US authors have already received citations from patents (60% more than expected), whereas H2020 publications by the same authors have not.[176]

The comparison of uptake of publications in patents between the H2020 and NSF baselines diverges from the result above, adding concerns about external validity to the limitations already reported above.

19.4.2.9. *Journalistic, Wikipedia and social media mentions*

Differential changes between NSF and H2020 publications by selected authors were statistically inconclusive on the altmetrics dimensions, meaning it was not possible to conclude robustly that H2020 publications or NSF publications performed better than the others on these dimensions.

In all cases, both NSF and H2020 publications performed much above world levels for their likelihood to be mentioned at least once on the platforms of interest. Scores were particularly strong for mentions in journalistic outlets (four to six times world level) or Wikipedia (five to eight times world level).

Except for journalistic mentions, the comparison of policy-related uptake between the H2020 and NSF baselines diverged from the results of the main analysis of selected US authors, adding concerns about external validity to the limitations already reported.

19.4.2.10. *Summary*

H2020 publication performances for selected US authors were much above world level as well as compared to the NSF achievements on the dimensions of 1) the average number of distinct countries of affiliation per publication, 2) share of academic-private co-publications, and 3) citation impact on all major indicators 4) share of publications available in OA.

Both US H2020 publications and NSF recorded high scores much above word level on 1) uptake in policy-related literature and 2) altmetrics mentions.

NSF publications by selected US researchers performed better than H2020 publications by the same researchers on 1) multidisciplinary, 2) average publication-level share of authorship held by women, 3) citation in patents (although this last finding is preliminary and very susceptible to change in the future, as full patent citation windows elapse).

[175] It should be noted that mentions of journal publications in policy-related documents is optimally computed using citation windows of 4 years, which have not elapsed here. Therefore, these findings are preliminary and subject to change.
[176] It should be noted that mentions of journal publications in patents is optimally computed using citation windows of 7 years, which have not elapsed here. Therefore, these findings are preliminary and subject to change.

19.5. Assessment of the benchmarking results

19.5.1. Effectiveness

Climate research funding by the NSF was an effective way to reach the goals that the NSF strives to accomplish. There is an impact on multiple levels: internationally, nationally, regionally, and locally. This can be exemplified by NSF's contributions to the IPCC at the international level, the NCA on a national level and research on extreme events (e.g. droughts, floodings, etc.) on a regional or local ecosystem level. This broad reach demonstrates that the research activities that are conducted contribute to reaching the organizational objectives of the NSF and even go beyond those objectives. Climate change cannot be looked at from a narrow perspective but should be studied from a holistic, global perspective, as environmental ecosystems do not stop at geographical boundaries. Therefore, one could say that the objectives of climate research implicitly go beyond the organizational objectives of the NSF (e.g. advance national health, prosperity, and welfare). Some interviewees suggested that the NSF could sometimes focus more on international challenges, as a lot of research focuses on complex US-focused issues. This is in line with the NSF organizational objectives and, therefore, within the boundaries of its mandate. However, as there are great contributions to international activities, it can be concluded that the current situation where there is a combination of studying the various levels of climate change is a positive aspect of NSF's climate funding.

The bibliometric analysis provides additional evidence of the extent to which the NSF research had an impact. First, NSF research results in studies that have a very strong citation impact profile. The H2020 publications by the same group of US authors score better. This can be explained by the fact that the US authors that receive H2020-funding are already a world-leading group of researchers in terms of scientific excellence. This, in turn, allows them to go further and obtain truly exceptional citation achievements. However, when placing it in a broader perspective[177] (i.e. compare the effects of funding for the selected US researchers against the general effects of H2020 funding), evidence suggests a more nuanced picture. For this set of data, the indicators suggest that H2020 green transition funding has been more effective than NSF green transition funding on balanced citation impact performances of supported researchers. With respect to other performance indicators, the NSF research, just like H2020 research, as well as compared to the world level. These indicators include the policy uptake, patents resulting from the NSF research, communication and dissemination methods and the extent to which multidisciplinary research was funded. Overall, the research activities provide good output in multiple areas such as scientific impact, multidisciplinary and policy uptake. Consequently, this means that the funding contributes towards reaching the NSF objectives, namely promoting the progress of science and advancing national health, prosperity, and welfare.

In terms of integrating multiple perspectives in all of NSF's activities, the NSF aims to have a broad representation within the organization, its portfolio, and other activities. For instance, the NSF aims to select a diverse set of reviewers for the proposal. Furthermore, activities by the Office of Integrative Activities and the existence of the previously mentioned RAISE proposals allow non-traditional proposals to be funded. As was stressed by multiple interviewees, in the context of the complexity of climate research, it is important to consider a broad range of perspectives and bring together knowledge from different disciplines. While it is difficult to say to what extent this has influenced meeting the NSF objectives, these activities certainly contributed to the progress in thinking about the complex challenges at hand. Furthermore, as it is not a one-way street, using scientific knowledge from other fields to do climate research also promotes the progress of science in those fields (e.g. the combination of Big Data and AI in climate research).

Finally, it is important to mention that the political landscape – as an external factor – has influenced the progress of science. There are multiple examples that show this. For instance, data collection has had to deal with periods of not being able to observe environmental phenomena because of government shutdowns. The resulting data inconsistencies influence the quality of the data. Additionally, the application and review processes and grant awards were halted or postponed during the government shutdowns. Furthermore, as explained before, during the benchmarking period, not all research could be conducted as some topics were deemed too politically sensitive. Furthermore, there were budget cuts at the NSF during the Trump administration. While it is difficult to pinpoint what the difference exactly is – since there is no counterfactual – it has influenced the extent to which results were produced and, therefore, also the impact of the research. An unexpected consequence of the (expected) budget cuts was that alternative funding sources were used (e.g. industry, philanthropists,

[177] The previous evidence refers to a subset of researchers, namely US researchers that are both funded by H2020 as well as the NSF.

states, etc.). An indirect result of this is that there are more direct linkages with a broader range of stakeholders. This does not imply that the results of these newly established connections also resulted in a better process, outcomes, or impacts. It merely shows that the connections have become stronger. In fact, the bibliometric analysis indeed shows that the subset of H2020 publications by selected US authors that included both academic and private firm authors is higher than the NSF publications by the same authors. Nevertheless, this can be a shift that is ongoing and has not yet resulted in publications.

19.5.2. Efficiency

With regard to the administration and management of the NSF, it is highly efficient. The NSF has existed for over 70 years and is a large organization with extensive experience in funding research, which has resulted in optimised and standardised processes. The supporting IT systems are well-developed. As they are integrated into the streamlined project application, selection and funding allocation processes, they work as they should.

In terms of the actual application process for proposals, including the merit review criteria, which are all clear and well-explained in the documentation. However, it should be noted that interviewees mentioned that it requires time to fully understand the grant award decision process, especially for young researchers. This potentially can lead to not funding bold and innovative projects, also due to conservatism that comes with only wanting to select the best projects and potentially missing riskier projects. The RAISE proposals fund these kinds of projects. However, other stricter criteria apply there.

In terms of efficient implementation of the funding processes by the NSF in the USA, the context of the political landscape should be mentioned as it sets the context. Interviewees mentioned that – due to political sensitivities – some topics in the realm of climate research were not always efficiently funded. It occurred that in the application process to get funding, researchers left out certain sensitive terms with regard to climate change in the application texts or titles to avoid being brought into a political discussion that potentially would lead to not getting funding for the research. This self-censoring has dampened the efficiency of the program as it had an impact on scientific freedom and made the entire process more difficult to assess due to the ambiguity it brought along.

The application process could be improved by considering ways to engage with the users more in case there are unclarities about the call for proposals or application process. Interviewees indicated that there is some room to ask for clarification about the call for a proposal or an opportunity to write a one-pager that can be discussed with the program manager. However, there is room to smoothen this process, as the answers to the questions are not always helpful, and different people responding could have different answers. Improving this would result in better proposals and a more efficient proposal writing process for the proposers.

With regard to monitoring and evaluation systems and feedback to policy processes, the NSF has multiple systems in place to ensure that the scientific results lead to constructive output. The NSF monitors both portfolio and performance metrics, some of which can be found online through NSF by the Numbers178. It is unclear whether all metrics are published through this online platform. Furthermore, there are independent audits of NSF's financial performance. Sometimes NSF is also involved in international benchmarking exercises for programs whose ultimate outcomes occur over time frames longer than grant periods. Since the NSF funds a wide range of scientific disciplines, there is a focus on monitoring and evaluating the whole organisation, not specifically the green transition activities. However, through the National Academies of Sciences, Engineering, and Medicine, publications are issued to inform policymakers on specific topics, such as climate research and the progress of science in those topics over the years. The topic of these studies can also be related to the USGCRP or are done by the USGCRP themselves. Finally, there is Congressional oversight, and each year, the NSF needs to request and substantiate the proposed year for the coming year.

[178] https://beta.nsf.gov/about/about-nsf-by-the-numbers

19.5.3. Relevance

The funding activities of climate research of the NSF are highly relevant to stakeholders' needs. These needs are in line with the overall objectives of the NSF since it contributes to understanding the international, nationwide, regional, and local environmental ecosystem dynamics. The contributions to the NCA and the IPCC show the relevance of the funding by the NSF, as these are prominent and highly valued publications for both policymakers as well as the general public. Furthermore, NEON is a good example of funds that are used to support research at the various levels of the United States' environmental ecosystem.

It should be noted that the NSF is not the only federal agency funding climate research. There are twelve other agencies that, to some extent, are involved, and they are united through the main coordinating body, namely the USGCRP. The NSF is one of the Parties contributing to it. Through this initiative, the NSF can leverage its activities to engage in multidisciplinary and multi-stakeholder projects. The NSF holds a unique position, also within the initiative, as it funds 25% of all basic science in the United States, and this number is higher for basic science in distinct fields (e.g. the Directorate for Geoscience provides 57% of the fundamental research in environmental sciences[179]).

The NSF has a system through which the thematic areas are kept up to date with technological, scientific, and socio-economic developments. These include the development of the decadal strategy plans, the triennial updates on this decadal plan, and the advisory committees, which are composed of leading scientists that consider the future of their respective disciplines. One of the interviewees indicated that a good example of this is that there is a big focus on (and bi-partisan agreement over the importance of) investing in AI and quantum computing. Therefore, research that combines those technologies with climate research is well-funded. The big challenges and known and unknown unknowns that come along with climate change require novel approaches, and this shows that the NSF indeed supports such novel approaches.

Finally, as mentioned before, the United States is geographically a large country with many different ecosystems. Therefore, multiple different impacts of climate change can occur in various parts of the country at the same time, such as droughts in some areas and flooding in others. NSF funds research into these 'niche' topics, and therefore, its activities are highly relevant to local communities as well.

19.5.4. Good practices

During the proposal review process, external reviewers are included to assess the proposals. The external reviewers are selected based on their specific expertise on the topic and general expertise on science and engineering to assess the broader implications or broader societal impacts. The NSF intends to have a broad representation of multiple stakeholders in the review process (including from diverse types of organizations). Additionally, proposers can also suggest reviewers they consider competent. Both the representation of a wide variety of stakeholders as well as the possibility for proposers to propose external reviewers helps the NSF keep up-to-date with use-inspired or upcoming research opportunities.

The call for proposals that the NSF publishes is very much standardised. They are easy to find and straightforward in terms of readability. Researchers indicated that this is appreciated, as sometimes calls from other funding agencies are difficult to process.

Interviewees indicated that the NSF could be lenient with regard to the disbursement of funding once the grant is awarded to a proposal. Some projects require more funding at the beginning rather than evenly distributed throughout a project due to larger investments upfront. The same holds true for the duration of the projects: there is room to prolong the project if needed. Especially in the context of the inter- and multidisciplinary projects that are needed to research the complex challenges that encompass climate change, the impacts of climate change and adaptation measures, it is very valuable that funders are flexible and interact with the researchers to understand their needs.

At the NSF, advisory committees play an active role in providing advice and recommendations to Directorates and Offices. The members of these advisory committees come from a wide range of stakeholders, including academia, the private sector and policymakers. The main roles of the committees are to be the base of contact between the NSF and the community, provide input, serve as a forum, and monitor the activities. They play a vital role in keeping the research on the scientific

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[179] NSF FY 2022 Budget Request to Congress

and technological frontier; through discussions on the disciplinary needs and opportunities, the role of research and education, integrations of novel methods and other disciplines and the implications for policy.

19.6. Short comparative analysis

The international benchmarking foresees a short qualitative comparative analysis of the study case with H2020. NSF represents one of four case studies, and the synthesized 2020 evaluation effort is still ongoing. Thus, the results for the overall comparison are not available yet (expected to be ready in late autumn 2022) and will be provided in an overall comparison across all benchmarking cases. However, the ACRP pilot already established four cross-cutting evaluation dimensions, which should be addressed in all benchmarking cases.

19.6.1. Strategic development

In terms of strategic development, the key question is whether the programme kept abreast with and adapted to changing or emerging global and national situations, such as the Paris Climate Accord and other international commitments.

In this regard, the picture is varied and complex. Although NSF-funded research consequently provided information for important international, national and regional climate assessments (e.g. IPCC and NCAs), shifting political priorities (depending on Administration taking office) and corresponding budgetary changes have had a strong influence on the quality of climate research. This is best illustrated by the US becoming a party to Paris Agreement (in 2015, during President Obama's term) and withdrawing from it in 2017 (during President Trump's administration). During the Trump administration President Trump on multiple occasions, proposed to have the budgets cut for Federal Agencies that fund climate science. Due to the power of Congress (which found funding (climate) science of importance), not all proposed budget cuts were approved. Nevertheless, it exemplifies the general context for climate research during the benchmarking period. An unexpected consequence of the weakened climate for science was that alternative funding sources were discovered (e.g. industry, philanthropists, states, etc.). While the effects of this change did not reflect in the bibliometric analysis, it shows the development of including a wider range of stakeholders in the science, which can be seen as a positive development, especially in the context of climate science (and SDG17). The objectives of climate research implicitly go beyond the organizational objectives of the NSF (e.g. advance national health, prosperity, and welfare). Therefore, it appears that the NSF would have the potential to focus more on international challenges.

Overall, it can be concluded that efforts towards the Green Transition have not been scaled up in the case of NSF as they have within H2020 at the highest political level (through the EU Green Deal).

19.6.2. Uptake of R&I results

The evidence base on this aspect is scarce due to the absence of evaluation reports and the fact that a substantial part of NSF research is fundamental science. Still, the bibliometric analysis indicates high policy uptake - the share of publications by selected US authors cited in policy-related documents was six times the expected (for both their H2020 and NSF publications).

Herewith interesting observation is also that H2020-funded publications saw more academic-private co-publications than NSF-funded publications (16% vs 7%, respectively), therefore fostering academic-private collaboration and contributing to the uptake of the results.

Next to that, NSF publications by selected US authors have already received citations from patents (60% more than expected), whereas H2020 publications by the same authors do not show such results.

Regarding social media uptake, in all cases, both NSF and H2020 publications performed much above world levels for their likelihood of being mentioned at least once on the platforms of interest. Scores were particularly strong for mentions in journalistic outlets (four to six times world level) or Wikipedia (five to eight times world level).

Also, the advisory committees play a positive role in the uptake of the results, connecting researchers with a wider range of stakeholders, including the private sector and policymakers. They help spotting out new opportunities, addressing the role of research and education and the implications for policy.

19.6.3. Networking and infrastructure

NSF-funded climate research activities cannot be assessed without the broader context of climate research in the US. The USGCRP covers all federal agencies that fund climate research. Therefore all activities that the NSF is involved in within this context have contributed positively to the networking effects. On an annual basis, the NSF funds around 25% of all fundamental research (i.e. in all fields of science and engineering) supported by federal funding that is conducted by US colleges and universities. This number increases when looking at separate directorates that are in the scope of the benchmarking exercise. As fundamental science provides the basis for many other types of (applied) research, as it helps to understand the complex environmental dynamics and ecosystem, the NSF, therefore, plays a vital role in promoting the progress of science, not only for itself but also for the climate research community.

In terms of infrastructure, the NSF funds the National Ecological Observatory Network (NEON), a large-scale research infrastructure focused on observing long-term changes in terrestrial, aquatic and atmospheric ecosystems throughout the US. Without the NSF, such a vast data collection effort and subsequent research were not possible.

Again, the political landscape has had a profound effect on climate research in the US, and therefore the NSF has not achieved its full potential in building a climate network and a sound research infrastructure even though communication and dissemination activities were on the agenda and successful according to the bibliometric analysis.

19.6.4. Transdisciplinarity

The NSF funds a wide range of science and engineering fields. There are multiple ways through which the NSF aims to facilitate transdisciplinary research. First of all, there are the divisions and advisory committees specifically focused on integrating different disciplines and new approaches to research. Furthermore, there are the Office of Integrative Activities, specific programs such as the CoPe-program, and the RAISE proposals.

Evidence from the bibliometric analysis indicates that the selected US researchers tended to be above the world level in terms of multidisciplinarity for their NSF publications. Compared to the H2020-publications of the same authors, the NSF publications scored higher. As for interdisciplinarity, the set of H2020- and NSF- funded publications by selected US researchers scored on the world level. However, at the same time, the analysis showed that generally, this level (for both H2020- as well as NSF-publications) is higher.

Finally, the benchmark showed that over the benchmarking period, in terms of transdisciplinarity and finding the interface between the human and natural world, the activities and progress of the NSF- and H2020 activities converged. While both H2020 was ahead in successfully funding this type of research and the topic had been high on the agenda for the NSF, at the beginning of the benchmarking period, it was less successful than H2020.

19.7. Conclusion

Our findings from by evaluation are presented below.

Effectiveness: Overall, the collected evidence shows that the climate research that is funded through the NSF is an effective means to accomplish the NSF objectives. NSF plays a significant role in research that is conducted on multiple levels, ranging from international to local research. It, therefore, contributes to more than merely the NSF objectives itself. With regards to the impact of the research that was funded by the NSF, not only do the publications have a strong citation impact profile, but the publications also score well on other indicators such as policy uptake, patents, communication, dissemination activities and multidisciplinarity. However, the H2020 publications of the same US researchers appeared to have an even higher impact on the different previously mentioned indicators. It should be noted that the bibliometric analysis only used a subset of all NSF “green” publications and that, therefore, the results cannot be extrapolated to the entirety of the NSF. The NSF aims to support broad representation through both the organisation and portfolio and has multiple means to achieve this. During the benchmarking period, an influential hindering external factor for the progress of science (i.e. one of the NSF objectives) was the political landscape (i.e. the extent to which climate change was reflected as a political priority topic for the US Presidents).

Efficiency: Regarding the proportionality of costs to benefits of the research programme, it can be concluded that the administration and management of the NSF are efficient. As the NSF is a large organisation, there are well-developed and standardised systems and mechanisms in place. This resulted in streamlined project application, selection, and funding allocation processes. The merit review criteria are also clear and well-explained in the documentation. According to some interviewees, for some young researchers understanding these processes initially is challenging. This could potentially result in missed opportunities. An addition to the application process could be to integrate more user engagement, which would result in a stronger alignment between the needs of the NSF and the researchers. During the benchmarking period, the benefits of the research program were dampened by the political landscape, as not all climate research was the priority of the Trump administration. With regards to monitoring and evaluation systems and feedback to policy processes, the NSF has multiple systems in place to ensure that the scientific results lead to constructive output, including monitoring metrics, independent audits, international benchmarking exercises, publications of the National Academies, the input from advisory committees and the USGCRP.

Relevance: Finally, given the relevance (and evidence) of global climate change for the US public, scientific community as well as policymakers, the funding activities of climate research by the NSF can be seen as important (e.g. NCA, IPCC, etc.). They are in line with the overall objectives of the NSF, which all three consider a broader societal scope. The NSF funds research that considers climate from an international perspective to a local perspective. This helps in understanding the overall picture, but also specific local challenges, which would come in handy for climate mitigation and adaptation measures. As the NSF also contributes to the USGCRP, the NSF can leverage its activities through multidisciplinary and multi-stakeholder projects. Finally, there are processes in place to keep the NSF activities at the technological and scientific frontier. These include the development of the decadal strategy plans, the triennial updates on this decadal plan, and the advisory committees, which are composed of leading scientists that consider the future of their respective disciplines. This shows that the NSF aims to be and remain relevant for research into current and future challenges that a broad range of US stakeholders might face.

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19.9. Annexes

19.9.1. Guiding questions for stakeholder interviews

Greetings and acknowledgement of time.

Introduction by Technopolis Group.

– Could you introduce yourself, incl. your current position and your relationship to NSF?

– What could EU research funding in the field of climate change and adaptation learn from the NSF?

– We would like to ask you for your own and the evaluation committee’s/organisation's perception of the NSF´s performance over the past years?

– What effects /societal changes has NSF contributed to – and in what way (changed the understanding of climate challenges, new policies, changed behaviour, new synergies with other projects, etc.)?

– Can you reflect on the organisational set-up of the NSF?

– What about your (NSF’s) institutional perception regarding efficiency (in terms of funding objectives) and effectiveness (regarding overall programme delivery)?

– Do you think that the NSF has been delivering as expected in the area of climate change adaptation and green transition?

– What about the management of NSF? What has worked well, and what has been challenging?

– Do you have proposals for changes that enable NSF to be better adapted to challenges and research needs in the future? For example, changing priorities, etc

– Is there any identifiable strategy regarding the embedding of NSF within European /other international research funding programmes and objectives?

– How would you rate its relevance for the US (scale 1 to 5)?

– Where would you see strengths/weaknesses of the NSF in terms of its embedding with the overall funding programme landscape in the US… and in Europe? What would you need in order to foster both US climate-related research, as well as European linkages?

– Has NSF influenced national and international research priorities?

– What are the main solutions to support/enable/channel research follow-up into concrete transition measures?

- What do you believe to be required from the policy side to enable lasting green transition effects?
- What would be the NSF's role in this process?
- In which ways is the NSF replying to these challenges?
- Do you think that the funds allocated through NSF could have been used in another way that would, to a greater extent, have contributed to outstanding research and relevant knowledge related to climate systems, effects and change?
- Could you reflect on the role of the USGCRP on the NSF?
- Is there anything else important (not covered yet) that you'd like to add (thoughts on what worked well and what has been challenging at NSF)?

19.9.2. NSF list of interviews

During the period July-August 2022, we conducted a series of 3 semi-structured online interviews with researchers, NSF staff and others with NSF work experience. Each interview took roughly 60 to 90 minutes and followed a set of guiding questions for the different scenarios comprising public and private interlocutors. Our questions generally followed the idea of having our interviewees themselves assess the NSF's strength and success stories, in addition to its overall efficiency, effectiveness, and relevance.

We also aimed at capturing those socio-political obstacles which prevent the deeper structural changes necessary to bring about the "green transition" and the role of publicly funded science in this process. Strategies for better knowledge generation and, thus, public policy input were collected from our interviewees.

All interviews were transcribed and qualitatively analysed. The overall response rate was low. While the US stakeholders we interviewed were very much involved and helpful for the benchmark, the period during which the interviewing phase was planned covered the summer holiday period. Many people we identified as potentially interesting to interview were not available for interviews for prolonged periods. Others indicated that they were not aware of H2020's activities and therefore did not feel comfortable cooperating with the exercise, as well as their perceived unfamiliarity with H2020 or their reluctance to some extent to assess the NSF as a whole. Some interviewees preferred to remain anonymous with regard to their answers to our study.

Name	Role
Amy Tuininga	Director, PSEG Institute for Sustainability Studies, College of Science and Mathematics
Anonymous interviewee	-
Maria Uhle	Program Director for International Activities in the Directorate for Geosciences at the National Science Foundation

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This document presents the annexes to the Evaluation study on the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness – Focus on activities related to the Green Transition – final report Phase 1.

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