European Commission

Partnership Evaluation Report: **European Partnership Clean Aviation Joint Undertaking (CAJU)**

Horizon Europe and the Green Transition Interim evaluation support study

Independent Expert Report

Research and Innovation

Partnership Evaluation Report: European Partnership Clean Aviation Joint Undertaking (CAJU)

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Manuscript completed in June 2024

PDF	ISBN 978-92-68-19826-1	doi:10.2777/403632	KI-02-24-843-EN-N

Luxembourg: Publications Office of the European Union, 2024

EUROPEAN COMMISSION

Partnership Evaluation Report: **European Partnership Clean Aviation Joint Undertaking (CAJU)**

Horizon Europe and the Green Transition Interim evaluation support study

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2024 Directorate-General for Research and Innovation EN

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EXECUTIVE SUMMARY

This report analyses the partnership Clean Aviation under the criteria of relevance, coherence, efficiency, effectiveness, EU-added value, additionality, directionality, international positioning, transparency and openness of the implementation of the partnership in relation to the Horizon 2020 and Horizon Europe objectives targeting a Green Transition.

The Horizon Europe (HE) Clean Aviation Partnership is a public-private partnership between the European Union and the European aeronautics industry and research organisations. The main objective is to contribute to reducing the ecological footprint of aviation by accelerating the development of climate-neutral aviation technologies for their earliest possible deployment. The HE Clean Aviation partnership is bringing together major European aviation private partners while the European Commission represents the public side. Clean Aviation builds on the work of its predecessors, Clean Sky and Clean Sky 2, with the Clean Sky 2 programme continuing to run until 2024.

The Clean Aviation programme is focused on three key thrusts – hybrid electric regional aircraft, ultra-efficient short and short-medium-range aircraft, and disruptive technologies to enable hydrogen-powered aircraft. Target technology readiness levels (TRL) are mostly between TRL 4 and TRL 6.

Both Clean Sky 2 and Clean Aviation are well aligned with the EU's objectives of achieving a green transition in Europe. Clean Aviation is introducing a step change. Clean Aviation's work is impact-driven, focussing on the next generation of regional and short/medium range aircraft, offering significant reductions in fuel burn and emissions compared to 2020 at a technology and industrial readiness level, allowing an introduction in the market by 2035. Technology maturation is being accelerated through integrated demonstrations.

Clean Sky 2 and Clean Aviation achieved a high level of efficiency in the implementation of their processes. Administration and management of Clean Aviation builds on the successful work of Clean Sky 2 with the same experienced and committed team involved and established processes.

In Clean Sky 2, major technological challenges have been addressed on a broad range of topics. Considering citation impact, Clean Sky 2 publications stand out for scientific excellence. Outputs and outcomes of the first Clean Aviation call are not yet visible; therefore, it is too early to assess Clean Aviation's effectiveness. There are sufficient measures in place to ensure that the objectives of the partnership are met. In addition, the Horizon Europe Clean Aviation partnership works closely with the European Aviation Safety Agency (EASA) in all projects, thereby allowing certification processes to start early on and in parallel, which would previously have been following technology development.

Clean Sky 2 created strong synergies within its membership and coordination with member states through the states' representative group. Clean Sky 2 Synergy labels are an effective mechanism to create synergies with national and regional funding. Clean Aviation is building on this as assuring cooperation and synergies with other partnerships and alignment with other streams of funding has been identified as crucial to achieving the overall objectives of reaching climate-neutral aviation with large investments needed. Successful work started in Clean Sky 2 is being continued to meet the more ambitious objectives.

By means of open calls and outreach to newcomers, Clean Aviation creates considerable EU-added value to the European aviation ecosystem by providing an arena for the EU industry, research organisations and other relevant stakeholders to meet, collaborate and work towards a common vision.

Clean Aviation is perceived as a prominent player at the international level.

Key definitions, acronyms, and glossary

AZEA	Alliance for Zero-Emission Aviation
CAJU	Clean Aviation Joint Undertaking
CEF	Connecting Europe Facility
CEI	Call for Expression of Interest
DEP	Digital Europe Programme
EASA	European Union Aviation Safety Agency
EIS	Entry into Service
ESIF	European Structural and Investment Funds
FAA	Federal Aviation Administration
HPA	Hydrogen Powered Aircraft
HER	Hybrid Electric Aircraft
IADP	Innovative Aircraft Demonstration Platform
IKAA	In-kind contributions to Additional Activities
IKC	In-kind contributions
IKOP	In-kind contributions to Operational Activities
IRL	Integration Readiness Level
ITD	Integrated Technology Demonstrator
JU	Joint Undertaking
MoU	Memorandum of Understanding
MRL	Manufacturing Readiness Level
NEXTGenEU	Next Generation EU – funding mechanism
PPP	Public Private Partnership
SAB	Scientific Advisory Body
SC4	Societal Challenge 4 (Smart, Green and Integrated Transport)
SESAR	Single European Sky Air Traffic Management Research Joint Undertaking
SME	Small and Medium-Sized Enterprise
SMR	Ultra-Efficient Short-Medium Range Aircraft
SRIA	Strategic Research and Innovation Agenda
SRG	States Representatives Group
SRL	Systems Readiness Level
TA	Transverse Activities
TCCG	Technical Committee Coordination Group

1. Introduction

1.1. Purpose and Scope

This report on the Clean Aviation Partnership (including reference to its predecessor Clean Sky 2) is part of the ex-post evaluation of H2020 and the interim evaluation of Horizon Europe activities related to a Green Transition.

The partnership report builds on the Clean Sky 2/Clean Aviation progress report (evaluation in phase 1). It aims to provide evidence on the relevance, coherence, efficiency, effectiveness, EU added value, additionality, directionality, international positioning and transparency and openness of the implementation of the partnership in relation to the Horizon 2020 and Horizon Europe objectives targeting a Green Transition.

1.2. Methodology

The partnership report follows the principles of a case study analysis and comprises a mixed-method approach of both quantitative and qualitative data analysis.

The quantitative data analysis comprises an analysis of the project portfolio of the institutionalised partnership based upon eCorda from March 2023. The time horizon covered in the analysis is 2014 to 2022. The qualitative analysis comprises desk research and text analysis of the partnership strategic documents and existing monitoring, progress, and evaluation reports.

In addition to the desktop research activities, interviews were conducted with a total of 15 interviewees, including representatives from the partnership, two representatives from the European Commission and three project coordinators. All types of members (industry, SME, research institutes and universities) have been included. The interviews followed a semi-structured, exploratory approach based on guidelines referencing the evaluation questions in focus.

The data collection process for the partnership evaluation comprised two phases, incorporating information from both H2020 and the initial phase of the partnerships in Horizon Europe. The primary data collection was concluded by July 2023. Supplementary data from the forthcoming Biennial Monitoring Report 2024 was incorporated in December 2023. Due to the short runtime of the Horizon Europe Partnerships, it is noteworthy to bear in mind that while the activities of the first phase have commenced in 2022 and 2023, the planning and definition phase of the second phase is currently ongoing. As a result, very limited results are available in support of the implementation objectives of this report.

2. Background of Clean Aviation

The Horizon Europe Clean Aviation partnership is the research and innovation programme that is set up to “contribute to reducing the ecological footprint of aviation by accelerating the development of climate-neutral aviation technologies for their earliest possible deployment, therefore significantly contributing to the ambitious environment impact mitigation goals of

the European Green Deal"[1][2]. The Horizon Europe Clean Aviation partnership and the Joint Undertaking have been established by the Council Regulation (EU) 2021/2085 of 19 November 2021.[3]

Clean Aviation partly builds on the work of the Clean Sky 2 Joint Undertaking programme, which will continue to run until 2024. In 2014 Clean Sky 2 replaced and succeeded the Clean Sky Joint Undertaking established in 2008.[4] Clean Sky and Clean Sky 2 aim to reduce aviation's environmental impact by accelerating the development and deployment of cleaner air transport technologies and, in particular, the integration, demonstration, and validation of these technologies. Besides improving the environmental impact of aeronautical technologies, including those related to small aviation, the objective of Clean Sky 2 is also **to develop a strong and globally competitive aeronautical industry and supply chain in Europe.**

Clean Aviation's work is impact-driven, focussing on the next generation of regional and short/medium range aircraft flying on hydrogen or electricity. Aircraft category targets include offering 30 to 50% lower fuel burn compared to 2020 and significant emissions reductions[5] at a technology and industrial readiness level, allowing an introduction in the market by 2035, thus making preparations needed for climate-neutral aviation by 2050. Clean Aviation is organised in two phases. In phase 1, between 2022 and 2028, development of concepts, technology options and trade studies take place. In phase 2, from 2025, technology maturation is being accelerated through integrated demonstrations (see Figure 1).

Clean Aviation is co-funded by the European Union through the Horizon Europe research and innovation programme and industry funding. The funding streams (2022-2031) are:

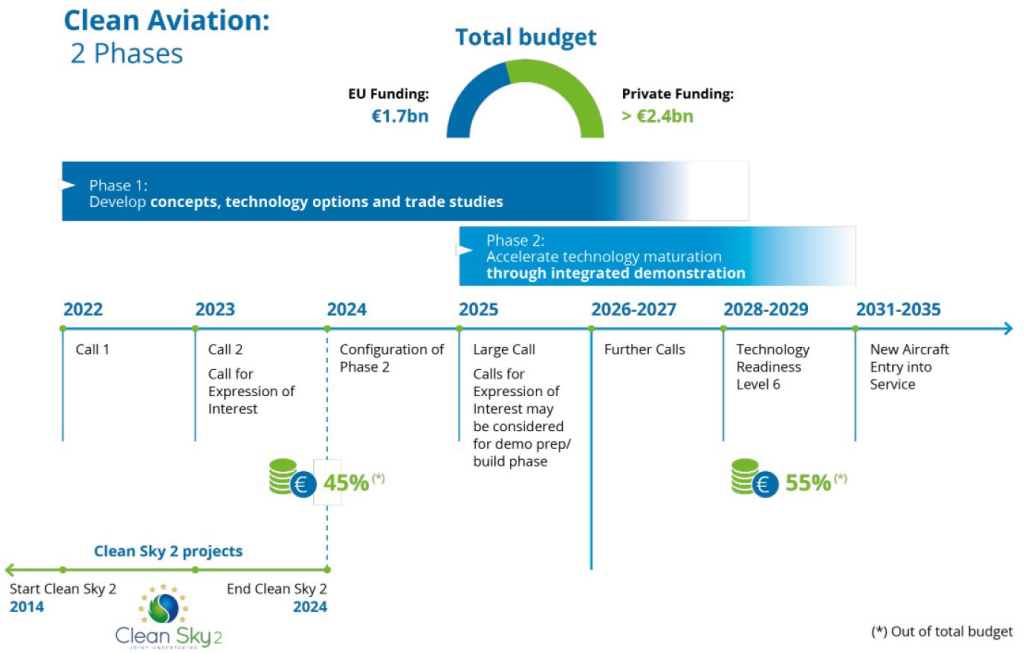
- Horizon Europe: EUR 1.7 billion
- Private Members: EUR 2.4 billion

The total administrative cost is up to EUR 78.4 million, which includes up to EUR 39.223 million from the EU and up to EUR 39.223 from private members[6].

It is planned to allocate about 45% of the budget to phase 1 and the remaining 55% to phase 2.

1 OJ L 427, 30.11.2021, Art. 47 (1).
2 OJ L 427, 30.11.2021, Art. 47 (1).
3 OJ L 427, 30.11.2021, p. 17; in the following referred to as "Single Basic Act".
4 Annual Accounts of Clean Sky 2 2014 p. 3
5 Source: Clean Aviation overview and structure. https://www.clean-aviation.eu/programme-overview-and-structure
6 OJ L 427, 30.11.2021, Art. 60, 61.

Figure 1: Timeline of Clean Aviation and Clean Sky 2 projects



Source : https://www.clean-aviation.eu/sites/default/files/2023-04/Timeline.pdf [05.06.2023]

In comparison, funding for Clean Sky 2 is broadly in the same orders of magnitude and involves an EU contribution (financial) from the Horizon 2020 programme budget of EUR 1.755 billion. It is complemented by the in-kind contributions from the private members related to the Programmes' activities [IKOP] and will be leveraged by further additional activities [IKAA] of the private members funded at national, regional, and private levels, leading to a total public and private investment of approximately EUR 4 billion. Guidelines on reporting IKAA for Clean Sky 2 state that no disclosure of the individual shares of the private members and the national co-funding is needed.[7] Hence, it is not possible to distinguish between private and public investment.

2.1. Governance of Clean Aviation

As an institutionalised Public Private Partnership (PPP), there are clearly defined roles for co-governance and membership, which are set out in the Council Regulation of the Joint Undertaking.

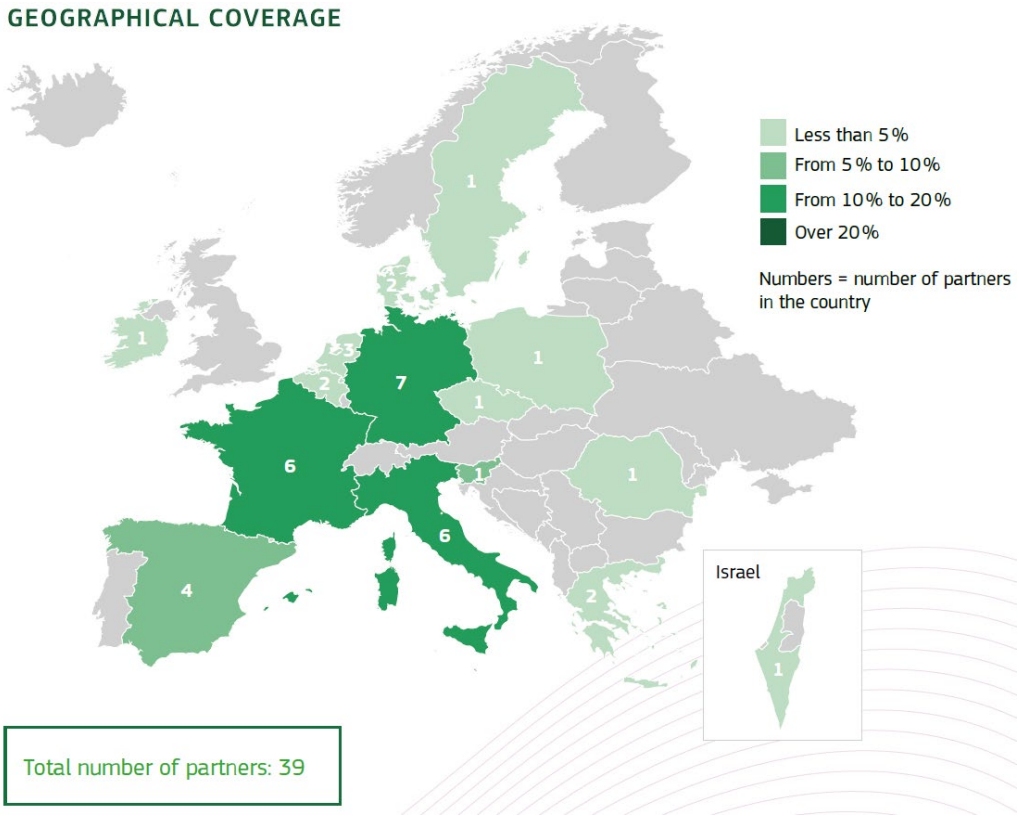
The Private Members of Clean Aviation are composed of 59 Founding and Associated Members as of December 2023[8] (see a list of names in the Annex). Figure 2 depicts the geographical coverage of Members as of 2022. Founding Members and Associated Members jointly commit to carrying out research and innovation activities, with the aim of achieving the high-level objectives of the initiative and supporting the programme with in-kind contributions, contributing a total of at least EUR 2.4 billion to Clean Aviation. Additional

[7] Source: Clean Sky 2 In-kind contribution procedure -for Additional Activities (IKAA)- Revised version December 2016, p.4.

[8] https://www.clean-aviation.eu/members [27.02.2024]

activities may include the development and testing of components, supporting technologies, or accompanying manufacturing methods and techniques, thereby contributing to the overall objectives of Clean Aviation. Options mentioned in the Single Basic act are[9]: (a) activities covered under the indirect actions of the Clean Aviation Joint Undertaking but not funded under such indirect actions; (b) activities directly linked to the Clean Aviation Joint Undertaking work programme; (c) research and innovation activities building on activities funded by the Clean Aviation Joint Undertaking or its preceding initiative; (d) the research and innovation activities of projects with a clear link to the Strategic Research and Innovation Agenda, and co-funded under national or regional programmes within the Union; (e) private research and innovation projects complementing projects on the Strategic Research and Innovation Agenda as well as activities contributing to the uptake of industry-specific skills across the value chain; (f) activities leading to the deployment or uptake of project results from the Clean Aviation Joint Undertaking or its preceding initiatives, or from both, that have not received any Union funding; (g) European standardisation and certification activities related to clean aviation solutions from the Clean Aviation Joint Undertaking projects or its preceding activities.

Figure 2: Clean Aviation geographical coverage of Members.



Source: BMR 2022, p. 285[10]

A major change in comparison to Clean Sky 2 exists in relation to membership. In Clean Sky 2 there was an allocated budget for each member type. The funding repartition as set out in

[9] OJ L 427, 30.11.2021, Art. 62.
[10] For Clean Aviation partners are members.

the Regulation, up to 40% of the Union's available funding is ring-fenced for its 16 leaders and their Affiliates, up to 30% of the Union's funding is available for Core Partners, and at least 30% will be awarded via competitive Calls for Proposals and Calls for Tenders. In Clean Aviation all funding is awarded in Open Calls, irrespective of membership.

In line with the activities (i.e. the integration and demonstration of disruptive aircraft technological innovations, which imply high TRL), the majority of members of Clean Aviation are from industry (54%), followed by public research organisations (22%) and universities (14%) and SMEs (10%).

The governance framework of the Clean Aviation Joint Undertaking is as follows (see Figure 4):

- The **Governing Board** is the highest decision-making body. It is composed of representatives from the public and private members: Two representatives of the Commission on behalf of the European Union (holding 50% of the voting rights) and fifteen representatives of the private members, ensuring a balanced representation of the aeronautical value chain, such as aircraft integrators, engine manufacturers and equipment manufacturers, research and technology organisations, universities and higher education establishments, and SMEs (holding collectively the other 50% of the voting rights). Five of the present 16 members are female (31.3%).

- The **Executive Director** is responsible for the day-to-day management. As of 1 February 2019, Axel Krein was appointed[11] as Executive Director of Clean Sky 2 and is now in this role for Clean Aviation. He is assisted by the Programme Office.

- The **Technical Committee** shall develop and maintain the technological roadmap and strategy of the programme (SRIA), propose, prepare, and provide recommendations for the scope and programming of the research actions, while overseeing the technical strategy. The Technical Committee is composed of up to four Commission representatives and Union bodies, as decided by the representatives of the Union in the Governing Board, one representative from each member other than the Union, and one representative of the European Union Aviation Safety Agency (EASA). Six out of 60[12] representatives of the private members are female (~10%) as of January 2024.

  The programme's technical architecture is reflected through the establishment of a **technical sub-group** for each of the SRIA thrusts, namely Ultra-Efficient Short-Medium Range Aircraft (SMR), Hybrid Electric Aircraft (HER) and Hydrogen Powered Aircraft (HPA). In order to ensure the development of an integrated technology strategy and roadmap and to coordinate and harmonise the information and inputs to and from the thrust sub-groups, a **Technical Committee Coordination Group** (TCCG) is established. It is composed of up to three Members for each thrust sub-group, one Commission representative in the Technical Committee delegated to this group and one EASA representative.

Advisory bodies consist of:

- The **States Representatives Group** (SRG) reviews information and provides opinions on issues such as programme progress, updates on the SRIA, and links to other

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[11] The Programme Office is not a body in accordance with the Single Basic Act.
[12] https://clean-aviation.eu/members: SINTEF is represented by SINTEF AS and SINTEF Energy Research

(funding) initiatives. It consists of up to two representatives and up to two alternates from each Member State and associated country. Nine of the 35 members are female (25.7%)

- The **Scientific Advisory Body** (SAB) provides scientific advice to Clean Aviation, in particular on annual work programmes, revisions to the Strategic Research and Innovation Agenda (SRIA), the annual activity report and any other additional activities. Collectively, the members of the SAB have the necessary competences and expertise to cover the technical domain in order to make science-based recommendations to Clean Aviation. The Clean Aviation Governing Board appointed the members through an open selection process. The SAB has 15 permanent members, including a representative of the European Union Aviation Safety Agency (EASA). Two of the members are female (13.3%).

Figure 3: Clean Aviation governance structure

Source : https://www.clean-aviation.eu/about-us/who-we-are/organisation [01.06.2023]

2.2. Objectives

The Single Basic Act states the specific objectives of Clean Aviation:[13]

(a) to integrate and demonstrate disruptive aircraft technological innovations able to decrease net emissions of greenhouse gases by no less than 30% by 2030, compared to 2020 state-of-the-art technology, while paving the ground towards climate-neutral aviation by 2050;

(b) to ensure that the technological and the potential industrial readiness of innovations can support the launch of disruptive new products and services by 2035, with the aim of replacing

[13] OJ L 427, 30.11.2021

75% of the operating fleet by 2050 and developing an innovative, reliable, safe, and cost-effective European aviation system that is able to meet the objective of climate neutrality at the latest by 2050;

(c) to expand and foster integration of the climate-neutral aviation research and innovation value chains, including academia, research organisations, industry, and SMEs, also by benefiting from exploiting synergies with other national and European-related programmes and by supporting the uptake of industry-related skills across the value chain.

Clean Aviation's ultimate objective is to reach net-zero greenhouse gas emissions and to enable a climate-neutral aviation system in Europe by 2050.[14]

The Single Basic Act operationalises these into the general objectives of the Clean Aviation Joint Undertaking:

(a) to contribute to reducing the ecological footprint of aviation by accelerating the development of climate-neutral aviation technologies for earliest possible deployment, therefore significantly contributing to the achievement of the general goals of the European Green Deal, in particular in relation to the Union-wide net greenhouse gas emissions reduction target of at least 55% by 2030, compared to 1990 levels, and to a pathway towards reaching climate neutrality at the latest by 2050;

(b) to ensure that aeronautics-related research and innovation activities, with a particular focus on breakthrough technology initiatives, contribute to the global sustainable competitiveness of the Union aviation industry and to ensure that climate-neutral aviation technologies meet the relevant aviation safety and security requirements and that aviation remains a secure, reliable, cost-effective, and efficient means of passenger and freight transportation;

(c) to advance the European aviation research and innovation capacity.[15]

In addition, Clean Aviation has the objective to reduce *"the ecological footprint of aviation by accelerating the development of climate neutral aviation technologies for their earliest possible deployment."*[16]

Clean Aviation is building on what has been delivered by Clean Sky 1 and 2. The Clean Sky Joint Undertaking (Clean Sky 1) had the objectives to accelerate the EU development, validate and demonstrate clean air transport technologies, implement coherent European research efforts to improve the environmental impacts of air transport, create an innovative Air Transport System and accelerate the generation of knowledge to strengthen industrial competitiveness.

The regulation setting up Clean Sky 2 sets out in detail the targets for reductions in CO_2 and NO_x by 20 to 30% compared to a state-of-the-art aircraft entering service in 2014 and reducing noise levels[17].

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14 Clean Aviation, Strategic Research and Innovation Agenda, December 2021
15 Clean Aviation, Joint Undertaking, Amended Work Programme and Budget 2022-2023 p. 21
16 Council Regulation (EU) 2021/2085 of 19 November 2021. Official Journal: OJ L 427, 30.11.2021
17 COUNCIL REGULATION (EU) No 558/2014 of 6 May 2014 establishing the Clean Sky 2 Joint Undertaking

According to the Strategic Research and Innovation Agenda Clean Aviation will develop disruptive new aircraft technologies, which target net greenhouse gas (GHG) reductions of no less than 30%, compared to 2020 state-of-the-art technologies. The technological and industrial readiness allow the deployment of new aircraft with this performance no later than 2035, with the aim of replacing 75% of the world's civil aviation fleet by 2050. The aircraft developed will enable net CO_2 reductions of up to 90% when combined with the impact of sustainable 'drop-in' fuels, or zero CO_2 emissions in flight when using hydrogen as an energy source, see the current version of the Clean Aviation Strategic Research and Innovation Agenda (SRIA). To achieve net zero, the remaining emissions can be addressed by identifying other "additional and different technical and/or operational solutions"[18]. These include "net-zero or fully decarbonised sustainable aviation fuels",[19] opportunities for offsets, etc. While a reduction in the overall use of planes would clearly be the best way to reduce the need for additional solutions, current trajectories foresee an ongoing increase in traffic.[20]

Table 1 from the Strategic Research and Innovation Agenda (SRIA) summarises the targets.

Table 1: Clean Aviation aircraft category targets

	Key technologies and architectures to be validated at the aircraft level in roadmaps	Earliest EIS Feasibility*	Fuel burn reduction (technology-based) [1]	Emissions reduction (net – i.e. including fuel effect) [2]	The current share of air transport system emissions
Regional Aircraft	Hybrid-electric, distributed propulsion coupled with highly efficient aircraft configuration	~2035	-50%	-90%	~5%
Short-Medium Range Commercial Aircraft	Advanced ultra-efficient aircraft configuration and ultra-efficient gas turbine engines, ultrahigh bypass	~2035	-30%	-86%	~50%

18 SRIA, 2021, p 11
19 SRIA, 2021, p 13
20 EU COM, Fly the Green deal, 2022, p 23

	(possibly open rotor)				

[1] Improvement targets are defined as fuel burn reduction compared to 2020 state-of-the-art aircraft available for order/delivery

[2] Assumes full use of SAF at a state-of-the-art level of a net 80% carbon footprint (or, where applicable, zero-carbon electric energy)

*EIS: Entry into Service

Source: Clean Aviation, Strategic Research and Innovation Agenda, December 2021

Under Horizon Europe, Clean Aviation is established under the cluster of climate, energy and mobility further highlighting the contribution that aviation can make to Green Deal objectives as well as the need to make the industry more sustainable.

According to the Amended Work Programme, 2022/2023, there are two timelines for Clean Aviation to achieve its targets[21]:

2030: demonstrating and introducing low-emission aircraft concepts exploiting the research results of Clean Aviation, making accelerated use of sustainable fuels and optimised 'green' operations so these innovations can be offered to airlines and operators.

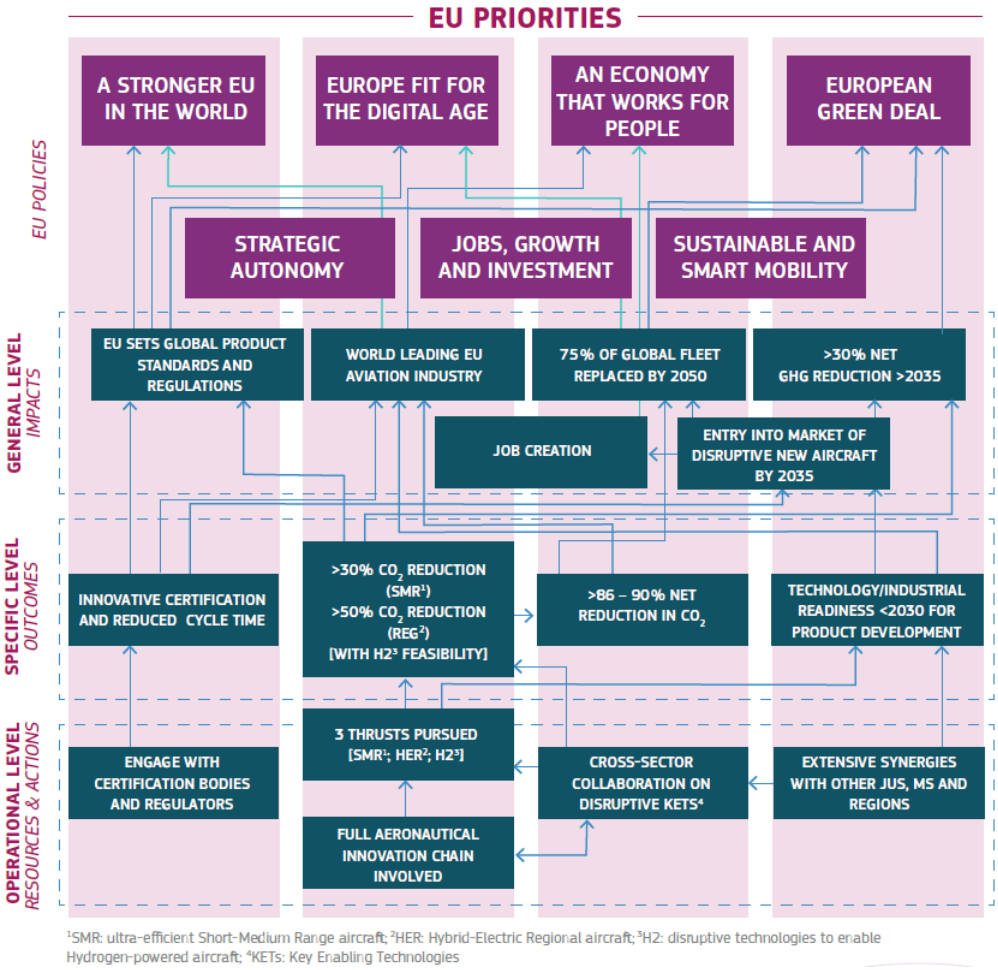
2050: climate-neutral aviation, by exploiting future technologies matured beyond the Clean Aviation phase coupled with full deployment of sustainable aviation fuels and alternative energy carriers such as hydrogen.

2.3. Intervention Logic

The activities of the partnership are expected to contribute to four of the six Commission priorities for 2019-24[22], namely to "A stronger Europe in the world", "A Europe fit for the digital age", "An economy that works for people" and the "European Green Deal" and the key objectives of achieving strategic autonomy and supporting jobs, growth and investment as well as the sustainable and smart mobility strategy[23]. The partnership-specific impact pathways towards these priorities and goals are depicted in Figure 5.

21 Clean Aviation, Joint Undertaking, Amended Work Programme and Budget 2022-2023
22 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024_en
23 SWD(2020) 331 final

Figure 4: Clean Aviation specific impact pathway



Source: BMR 2022, p. 282

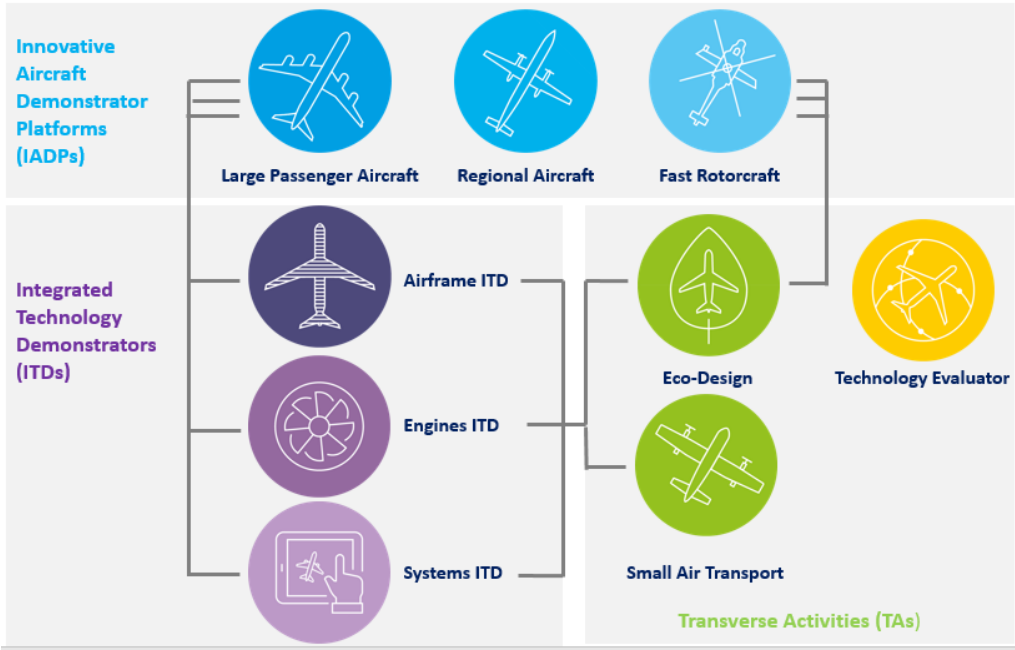
3. Implementation state of play

3.1. Thematic structure of R&I activities

Clean Sky 2 is organised with the structure depicted in the figure below, which consists of Integrated Technology Demonstrators (ITDs), Innovative Aircraft Demonstrator Platforms (IADPs) and Transverse Activities (TAs). With the Technology Evaluator (TE), a dedicated monitoring function has also been incorporated in Clean Sky 2.[24]

24 See CS2DP 2020 and CS2DP 2021.

Figure 5: Schematic Structure of the Clean Sky 2 Programme



- Innovative Aircraft Demonstrator Platforms (IADPs): IADPs carry out proof of aircraft systems, design, and functions on fully representative innovative aircraft configurations in an integrated environment and close to real operational conditions. To simulate and test the interaction and impact of the various systems in the different aircraft types, vehicle demonstration platforms cover large passenger aircraft, regional aircraft, and fast rotorcraft.

- Integrated Technology Demonstrators (ITDs): The ITD address the main relevant technology streams for all air vehicle applications. They are intended to allow the maturation of verified and validated technologies from their basic levels to the integration of entire functional systems covering a wide range of technology readiness levels. Each of the three ITDs orientates a set of technology developments that will be brought from component level maturity up to the demonstration of overall performance at a system level to support the innovative flight vehicle configuration. The three ITDs cover topics around airframes, engines, and systems.

- Several key areas are coordinated across the ITDs and IADPs through Transverse Activities where additional benefit can be brought to the Programme through increased coherence, common tools and methods, and shared know-how in areas of common interest. The three agreed Transverse Activities are Eco-Design considering the life-cycle optimisation of technologies, components and vehicles, Small Air Transport, and the Technology Evaluator to enable an independent Technology and Socio-Economic Impact Evaluation.

Clean Aviation is focused on three work strands or “Thrusts” to achieve its objectives[25]:

[25] CLEAN AVIATION Second Amended Workprogramme and budget 2022 - 2023

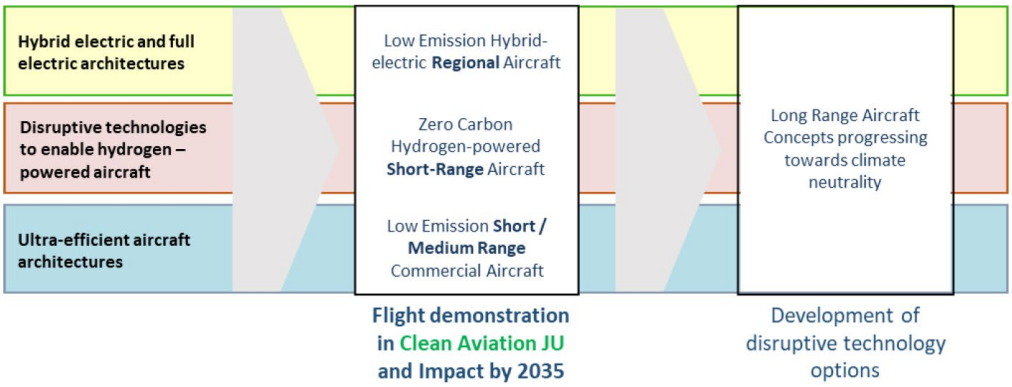
- Hybrid electric and full electric architectures – driving research into novel (hybrid) electrical power architectures and their integration and maturing technologies towards the demonstration of novel configurations, onboard energy concepts and flight control.

- Disruptive technologies to enable hydrogen-powered aircraft – to enable aircraft and engines to exploit the potential of hydrogen as a non-drop-in alternative zero-carbon fuel, in particular liquid hydrogen.

- Ultra-efficient aircraft architectures – to address the short-, medium-, and long-range needs with innovative aircraft architectures making use of highly integrated, ultra-efficient thermal propulsion systems and providing disruptive improvements in fuel efficiency. This will be essential for the transition to low/zero emission energy sources (synthetic fuels, non-drop-in fuels such as hydrogen), which will be more energy-intensive to produce, more expensive, and only available in limited quantities.

These thrusts are applied to Hybrid-electric Regional Aircraft (HER), Hydrogen-powered aircraft (HPA) and Short/Medium Range aircraft (SMR), as depicted in Figure 6 below.

Figure 6: Mapping of the research thrusts against aircraft categories and concepts



Source: Strategic Research and Innovation Agenda, December 2021

The Roadmap for each Thrust is depicted in Annex 8.1.3.

Target technology readiness levels (TRL) are mostly between TRL 4 and TRL 6.[26] Target TRLs differ between the thrusts.[27] SMR, for example, has, on average, higher TRLs than the HPA Thrust because H2 activities feed into SMR. The roadmaps for each thrust depicted in the Annex show how the TRL levels are expected to increase throughout the lifetime of Clean Aviation.

[26] There are a very small number of TLR2 as target TLR. For example, in the SMR Pillar where 2 target TLRs are at level 2.

[27] Depending on the project, it may integrate Systems Readiness Level (SRL), Manufacturing Readiness Level (MRL) and Integration Readiness Level (IRL).

At the time of writing this report, Clean Aviation has issued two calls for proposals. The first and second calls are structured by Thrust plus a transversal topic area. The total budget for the first call in 2022/23 is EUR 735.72m, and EUR 137.75m for the second.[28]

Table 2: Indicative budget for calls 1 and 2 by Thrust (EUR million)

	Call 1	Call 2	Total
HPA	182	65	247
HER	175	32	207
SMR	270	40	310
Transversal	108.	-	108
CSA	0.72	0.75	1.47
Total	735.72	137.75	873.47

Source: Clean Aviation, 2nd Amended Work Programme and Budget 2022 - 23

The topics to be addressed in the first two calls are clearly differentiated. I.e. topics covered in call 1 are not included in call 2. Examples include the Direct Combustion of Hydrogen in Aero-engines under H2 is included in call 1 but not 2, while Liquid Hydrogen Fuel Distribution Technologies is covered in call 2 but not 1.

The amended Work Programme and Budget 22/23 also includes follow-up activities for Clean Sky 2. They are set within the same structure as Clean Sky 2. The Clean Sky 2 follow-up activities are there to conclude the configuration of the main demonstrators, ensuring that Clean Sky 2's objectives are fully delivered, leverage any additional funding with the ESIFs and finalise the impact assessment strategy, including the criteria for the technical evaluator.

3.2. Project portfolios

Clean Sky 2 (H2020) Project Portfolio

The project portfolio of Clean Sky 2 comprised 561 projects funded in Horizon 2020. The current sum of the requested EC net contribution is EUR 1.6 billion, as - at the time of writing this report - technical activities are still on-going, and Clean Sky 2 funding consumption is expected until 2024. Compared with the net contribution within SC4 of H2020 the share is 28.4% and hence covers a large share of the overall funding for transport and mobility.

[28] Clean Aviation, Joint Undertaking, Second Amended Work Programme and Budget 2022-2023

Table 3: Type of organisations in Clean Sky 2 (H2020)

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1000)
		Nb	Share (%)	EUR (1000)	Share (%)	
HES	292	485	21%	166,908	10%	344.1
OTH	17	17	1%	5,027	0%	295.7
PRC	430	1308	56%	1,119,030	69%	855.5
PUB	16	16	1%	6,056	0%	378.5
REC	318	491	21%	325,503	20%	662.9
Total (All types)	**561**	**2317**	**100%**	**1,622,523**	**100%**	**700.3**

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.

A share of 56% of EC's net contribution to Clean Sky 2 has been allocated to private companies, 21% to higher education institutions and 21% to research organisations. Compared with all other Green Transition areas considered (SC2 to SC5), the project portfolio of Clean Sky 2 has lower participation of public bodies and other organisations (1% each in Clean Sky 2 vs. 5% each in all Green Transition areas), indicating a slightly less heterogenous composition of consortia. The main objective of Clean Sky 2 is the strengthening of the sector along the value chain; therefore there is less sector-specific need to integrate public bodies and other organisations.

The largest share of funding is allocated to Innovation Actions (IA, 85%), followed by Research and Innovation Actions (RIA, 15%). Compared with the aggregated Green Transition project portfolio, where Research and Innovation Action account for a share of 44%, it clearly shows the commitment to design for new, altered, or improved products, processes, or services. Projects include prototyping, testing, demonstrating, piloting, large-scale product validation and market replication on rather high Technology Readiness Levels (TRL). Lower TRL research in aviation can be found in H2020 outside the partnership in collaborative R&D projects inside the aviation topics of the Mobility for Growth calls. The total funding of research topics in aviation in H2020 is thus made up of the two partnerships, Clean Sky 2 and SESAR (1 and SESAR 2020) as well as the collaborative R&D projects. In terms of the EC contribution, Clean Sky 2 is six times as large as collaborative R&D in aviation (270 million euros). In terms of total cost, it is even ten times as large.

Table 4: Type of actions/instruments in Clean Sky 2 (H2020)

Action/instrument	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)
		Nb	Share (%)	EUR (1,000)	Share (%)	
JTI-CS2-RIA	222	740	31.9%	245,942	15.2%	332.4
JTI-CS2-IA	333	1560	67.3%	1,375,317	84.8%	881.6
JTI-CS2-CSA	6	17	0.7%	1,264	0.1%	74.3
All types	**561**	**2317**	**100.0%**	**1,622,523**	**100.0%**	**700.3**

Source: eCorda, own calculation.

Private companies accounted for two-thirds of the participation in Innovation Actions (65%), while REC and HES together had the largest share of participation in Research and Innovation Actions (60%).

Table 5: Share of participation by type of action/instruments in Clean Sky 2 (H2020)

Type of Action/instrument	HES	OTH	PRC	PUB	REC	Total (All types)
IA	14%	1%	65%	1%	19%	100%
RIA	36%	0%	39%	1%	24%	100%
CSA	6%	0%	35%	0%	59%	100%

Source: eCorda, own calculation.

Geographically, the eCorda statistics show that Clean Sky 2 is mainly concentrated in EU-14 countries plus the UK. Around 91% of the participations and 94% of the EC contributions are shared among this group. EU-13 countries have only half of the participation than the UK (5.5% compared to 12.1%), with an even less favourable share of EC contribution (3.5% and 11.8%). Participations from third countries are an exemption in Clean Sky 2. Only 9 participations from 4 countries are represented within the project portfolio.

Table 6: Group of countries of Clean Sky 2 (H2020)

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	528	1,954	84.3%	1,396,825	86.1%	714.9	21
EU-14	*514*	*1,826*	*78.8%*	*1,340,499*	*82.6%*	*734.1*	*13*
EU-13	*57*	*128*	*5.5%*	*56,326*	*3.5%*	*440.0*	*8*
H2020-associated (exclude UK)	51	74	3.2%	34,099	2.1%	460.8	5
United Kingdom	151	280	12.1%	191,600	11.8%	684.3	1
Third Countries	9	9	0.4%	0	0.0%	0.0	4
All-countries	**561**	**2,317**	**100.0%**	**1,622,523**	**100.0%**	**700.3**	**31**

Source: eCorda, own calculation.

In terms of participation pattern, France stands out with the highest share of participation (19%) and EC contribution in total funding (26%). Spain, the UK, Germany, and Italy follow with shares of participation at 16%, 12%, 12% and 13% and shares of funding at 13%, 12%, 17% and 14% respectively. All other countries' participation shares are in the single digits with respect to participation and funding.

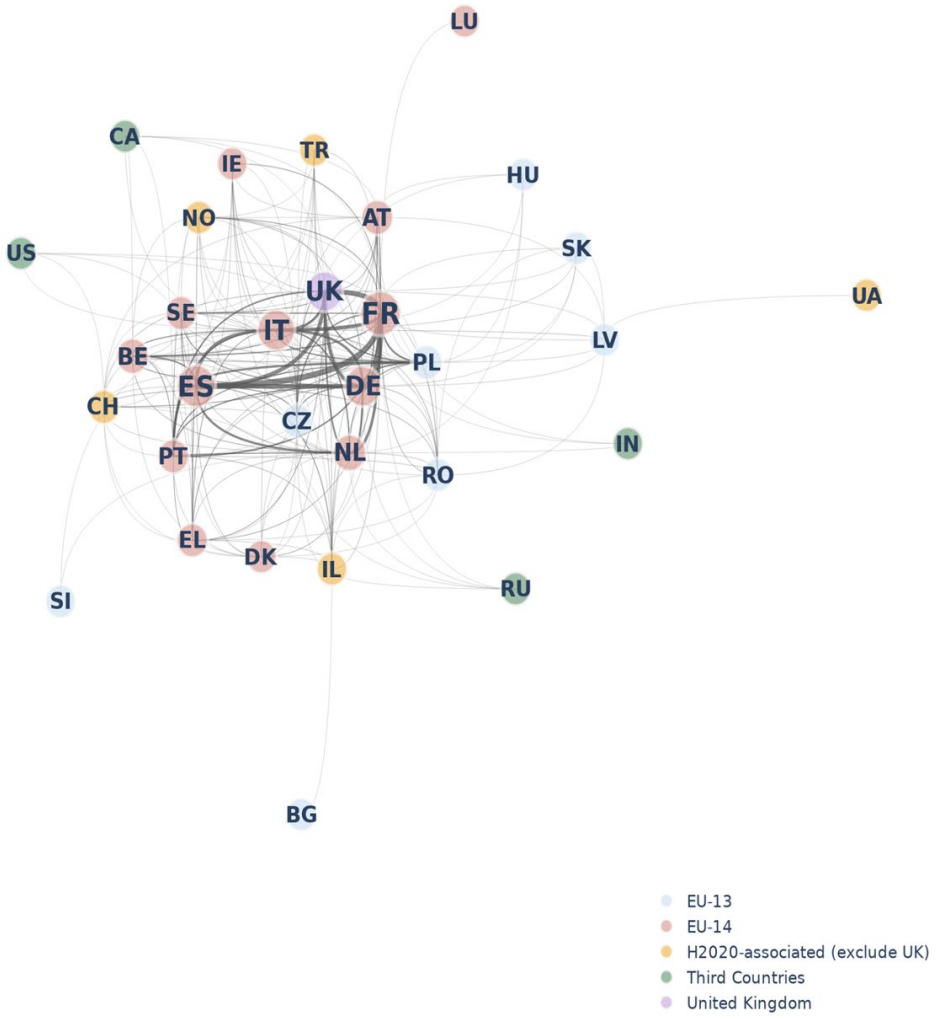
Table 7: Top countries of supported organisations in Clean Sky 2 (H2020)

Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Order
		Nb	Share (%)	EUR (1,000)	Share (%)		
France	170	444	19.2%	429,532	26%	967.4	1
Spain	168	368	15.9%	203,053	13%	551.8	2
United Kingdom	151	280	12.1%	191,600	12%	684.3	3
Germany	149	283	12.2%	277,102	17%	979.2	4
Italy	128	311	13.4%	232,014	14%	746.0	5
Netherlands	82	131	5.7%	73,355	5%	560.0	6
Belgium	57	88	3.8%	29,847	2%	339.2	7
Austria	37	71	3.1%	19,161	1%	269.9	8
Czechia	36	50	2.2%	28,344	2%	566.9	9
Switzerland	33	41	1.8%	9,534	1%	232.5	10
Sweden	29	39	1.7%	49,339	3%	1,265.1	11
Poland	22	47	2.0%	15,250	1%	324.5	12
Greece	22	34	1.5%	9,485	1%	279.0	13
Portugal	16	40	1.7%	9,442	1%	236.0	14
Romania	14	18	0.8%	10,875	1%	604.2	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 evaluation shows that France, Germany, and Spain are the three most often cooperating countries. Other important actors in the network are the UK, Italy, and the Netherlands as well as Poland.

Figure 7: Network of participating countries in Clean Sky 2 (H2020)



Source: eCorda, own calculation.

Clean Aviation (HE) Project Portfolio

When comparing Clean Aviation's portfolio to Clean Sky 2, it should be noted that the data only refer to the first call of Clean Aviation in 2022. So far, 20 projects with 244 single participants have been approved. The EU contribution amounts to 653.9 million euros. This represents about 40% of the Clean Sky 2 volume. The projects are, on average, twice as large (1.329 million Euro EC contribution per participation) than in Clean Sky 2 (about 700,000 Euros).

Three-quarters of the EU funds and 61% of the participation are in private companies. Thus, EC contributions are somewhat more concentrated on the industry in this call than in Clean

Sky 2 (75% compared to 69%). While the participation of research organisations is at about the same level as in Clean Sky 2, the share of higher education institutions regarding budget is lower (6% compared to 10%) at this stage of the programme.

Table 8: Type of organisations in Clean Aviation (HE)

Type of organisation	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1000)
		Nb	Share (%)	EUR (1000)	Share (%)	
HES	19	87	18%	38,535	6%	442.9
OTH	7	9	2%	5,321	1%	591.2
PRC	20	299	61%	487,207	75%	1,629.5
PUB	0	0	0%	0	0%	N/A
REC	19	97	20%	122,854	19%	1,266.5
Total (All types)	**20**	**492**	**100%**	**653,916**	**100%**	**1,329.1**

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 Clean Aviation is an impact-driven partnership, it operates via Innovation Actions. Therefore, the first call referred exclusively to Innovation Actions. Additionally, there is only one CSA project in the portfolio so far (European Clean Aviation Regional Ecosystems). While the CSA is mainly conducted by other actors (in this project, regional associations) and a private company, 61% of the IA participations are private companies. The main difference to Clean Sky 2 so far is, therefore, the absence of RIA projects in the first call.

Compared with the entire Cluster 5 project portfolio where Research and Innovation Actions account for a share of 39% of participations and about a third of EC contribution it clearly shows the commitment of Clean Aviation to design for new products on rather high Technology Readiness Levels. Outside the Clean Aviation partnership, there were 7 call topics related to aviation in the WP 2021/2022, five topics in destination 5 and two in destination 6. A total of 25 projects are funded here. But the projects are considerably smaller than those inside the partnership, the EU contribution amounts in total only to 108.8 million euros. Among them, only 3 Innovation Actions are funded in destination 6. All other projects (22 from 25) are Research and Innovation Actions (in Destination 5). The RIA projects aim at TRL 2-4 by the end of the project. The share of universities is much higher than in Clean Aviation, with 33% of EU contribution and participation in these RIA projects (in Destination 5).

Table 9: Type of actions/instruments in Clean Aviation (HE)

Action/instrument	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)
		Nb	Share (%)	EUR (1,000)	Share (%)	
HORIZON-JU-IA\HORIZON-A	19	488	99.2%	653,196.0	99.9%	1,338.5
HORIZON-JU-CSA\HORIZON-	1	4	0.8%	720.0	0.1%	180.0
All types	**20**	**492**	**100.0%**	**653,916.0**	**100.0%**	**1,329.1**

Source: eCorda, own calculation.

Table 10: Share (%) of participation by type of action/instruments in Clean Aviation (HE)

Type of Action/instrument	HES	OTH	PRC	PUB	REC	Total (All types)
IA	18%	1%	61%	0%	20%	100%
RIA	0%	0%	0%	0%	0%	0%
CSA	0%	75%	25%	0%	0%	100%

Source: eCorda, own calculation.

Geographically, the eCorda statistics show that Clean Aviation is mainly concentrated in EU-14 countries and the UK. Around 91% of the participations and 92% of the EC contributions are shared among this group. This is the same geographical distribution as in Clean Sky 2. The UK and third countries did not receive EC funding in the first call. The number of participations from third countries is as low as it was in Clean Sky 2.

Table 11: Group of countries of Clean Aviation (HE)

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 (%)		
EU-27	20	439	89.2%	641,720	98.1%	1,461.8	16
EU-14	*20*	*410*	*83.3%*	*601,071*	*91.9%*	*1,466.0*	*12*
EU-13	*14*	*29*	*5.9%*	*40,650*	*6.2%*	*1,401.7*	*4*
Associated (excl. UK)	7	11	2.2%	12,196	1.9%	1,108.7	4
United Kingdom	13	36	7.3%	0	0.0%	0.0	1
Third Countries	5	6	1.2%	0	0.0%	0.0	3
All-countries	**20**	**492**	**100.0%**	**653,916**	**100.0%**	**1,329.1**	**24**

Source: eCorda, own calculation.

It is also worth noting that EU-13 countries are involved in most projects (14 out of 20 projects), while in Clean Sky 2, there were many projects (90%) with no EU-13 participation at all. Thus progress on widening countries' participation has been made.

Table 12: Top countries of supported organisations in Clean Aviation (HE)

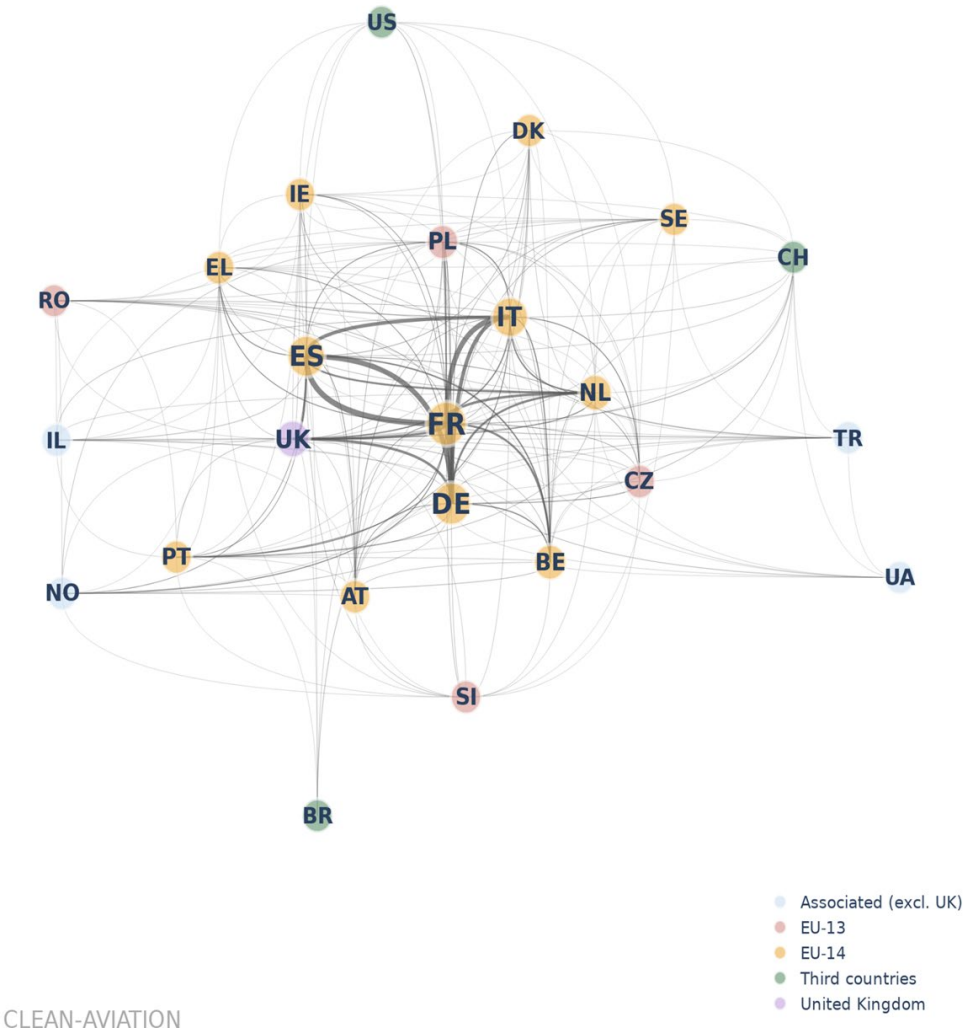
Top 15 country	Number of projects	Participations		EC contribution		EC Contr. per part. (EUR 1,000)	Order
		Nb	Share (%)	EUR (1,000)	Share (%)		
France	16	104	21,1%	204.899	31%	1.970,2	1
Germany	19	86	17,5%	172.157	26%	2.001,8	2
Italy	16	61	12,4%	80.936	12%	1.326,8	3
Spain	15	75	15,2%	56.477	9%	753,0	4
Netherlands	14	27	5,5%	30.682	5%	1.136,4	5
Belgium	12	20	4,1%	18.795	3%	939,8	6
Sweden	4	5	1,0%	18.217	3%	3.643,5	7
Czechia	7	9	1,8%	17.648	3%	1.960,9	8
Poland	7	13	2,6%	14.281	2%	1.098,5	9
Slovenia	5	5	1,0%	6.748	1%	1.349,7	10
Austria	7	8	1,6%	6.421	1%	802,6	11
Ireland	5	5	1,0%	5.393	1%	1.078,6	12
Greece	8	9	1,8%	3.713	1%	412,6	13
Romania	2	2	0,4%	1.973	0%	986,3	14
Denmark	4	4	0,8%	1.812	0%	453,1	15
Portugal	4	6	1,2%	1.567	0%	261,2	16
United Kingdom	13	36	7,3%	0	0%	0,0	17

Source: eCorda, own calculation.

In terms of participation pattern, France stands out with the highest share of participation (21%) and EC contribution in total funding (31%). Germany accounts for 18% in terms of participation and 26% of EC contribution in total funding, followed by Italy (12% in

participation and EC contribution) and Spain (15% in participation and 9% in EC contribution). All other countries' participation shares are in the single digits with respect to participation and funding. UK participated in 13 out of 20 Call1 projects and received no EU funding, but the UK guarantee scheme for Horizon Europe financially supported the UK-based stakeholders.

Figure 8: Network of participating countries in Clean Aviation (HE)



Source: eCorda, own calculation.

The network analysis based on the number of collaborations among organisations from each pair of countries in the projects of the first call shows that France, Germany, Italy, and Spain are the four most often cooperating countries. Other important actors in the network are the UK and the Netherlands. Although this network analysis is based on only 20 projects, it shows a similar pattern as in Clean Sky 2.

The share of female participation in Clean Aviation is 16%, thus being lower than in most other partnerships covered in this study, with shares ranging between 13% and 39% (see Annex 8.2.1).

3.3. Other Activities

Apart from research activities, there are supporting activities mainly carried out by the Executive Director and the Programme Office. Communication activities include presence at industry events and conferences, organizing own events, publications, and awards as well as digital tools and platforms. Coordination activities seek alignment with regional, national, and international organisations.

Clean Aviation's communication strategy is built upon two main pillars, namely, to increase awareness of Clean Aviation and to disseminate Clean Aviation's main activities and results. This includes presence at industry events and conferences (e.g., stands at the ILA Berlin Air show, the European Parliament, the ICAS congress in Stockholm and the Towards Sustainable Aviation Summit (TSAS) in Toulouse) and the organisation of the Clean Aviation Annual Forum which brings together key players in the aviation industry, including EU policy makers, manufacturers, academia, airlines, and press.

Publications include summaries and stories of research results as well as studies commissioned by Clean Aviation, e.g. an economic impact assessment or a description of collaborative activities with Member States. The "High Five Award" is a series of awards to individuals who exemplify Clean Aviation's commitment to climate-neutral aviation. A new Digital Communication Strategy was set up in 2022 to spread unified messages across multiple channels and to reach different target audiences.

Coordination activities at the European level include alignment with other partnerships and with other funding on regional, national, and European levels, e.g. with the European Structural and Investment Funds, with Memorandums of Understandings/Cooperation (MoUs/MoC) being one established way of working with national and regional authorities and organisations. Dissemination and coordination activities also take place on an international level, including with the IC–O (International Civil Aviation Organisation). Clean Aviation is also a member of AZ–A (Alliance for Zero Emission Aircraft), initiated by the European Commission. The objective of AZEA is to prepare the market for the entry into service of zero-emission aircraft, especially with a view to the impact on airport infrastructures or airline business models, identifying the challenges posed by zero-emission aircraft and proposing practical solutions.[29]

The partnership launched in May 2023. after its establishment a call for expression of interest (CEI) to recruit additional Associated Members in addition to the Associated Members that the Governing Board already approved in December 2021[30]. This CEI successfully resulted in the accession of 20 new Associated Members from 12 different countries[31] and increased the total number to 59 private members. The CEI was open to all interested entities willing to engage with Clean Aviation on a long-term basis, leading together with the European Union and the Clean Aviation private members, the way towards climate-neutral aviation. Stakeholders already in a successful Clean Aviation project were also invited to become

[29] https://defence-industry-space.ec.europa.eu/eu-aeronautics-industry/alliance-zero-emission-aviation_en

[30] https://clean-aviation.eu/sites/default/files/2022-01/CAJU-GB-2021-12-16-Decision-Associated-Members_signed.pdf [27.02.2024]

[31] https://clean-aviation.eu/media/news/the-clean-aviation-joint-undertaking-welcomes-20-new-associated-members [27.02.2024]

members of the partnership. The expansion of membership would be favourable for the partnership, as the new members contribute to the overall minimum level of in-kind contribution to be brought to the Joint Undertaking and 50% of the financing of the administrative costs of the partnership as well. Possible additional CEI may be considered as appropriate and if technically justified.

4. Findings

4.1. Relevance

Clean Aviation, just like its predecessor Clean Sky 2, is well aligned with the political objectives and EU strategies as described, for example, in the Single Basic Act[32] and expressed in the introduction to the Amended Work Programme and Budget 2022/23 (see also section 4.2 above on the objectives). The main aim is to reduce emissions in aviation. Both Clean Sky 2 and Clean Aviation, therefore, clearly contribute to achieving the Green Transition in aviation. However, Clean Aviation is operating on a shorter timescale than Clean Sky 2 by aiming to pave the way for the introduction of a new aircraft into the market, even aiming to "skip a generation" of aircraft, as expressed by an interviewee. Compared to Clean Sky 2 it is aiming at higher TRL levels to achieve this.

Clean Sky demonstrated flexibility in adjusting programme objectives from Clean Sky 1 to Clean Sky 2 and across the calls of Clean Sky 2 by focusing more and more on emissions reduction. This is also demonstrated in Clean Aviation, where the objectives of a reduction in emissions due to changes in aircraft type and changes across the global aircraft fleet are envisaged by 2050, delivering up to 90% of CO_2 emission reductions, finally leading to zero CO_2 emissions with hydrogen.

Clean Aviation focuses on aircraft segments where energy use and emissions are high: the regional and short-medium range aircraft. These segments account for roughly 55% of the total CO2 emissions from the global fleet. For roughly, regional aircraft perform about 40% of the total departures and around 36% of the total flown hours[33]. Clean Aviation aims at developing aircraft technological innovations for regional and short-medium range aircraft with -30% GHG emissions (compared to 2020 state-of-the-art) and supporting their entrance into the market by 2035. Other aircraft, such as helicopters or long-range are not included as outlined in section 5.1. However, it has been observed by an interviewee that many of the challenges for the engine or aircraft body are also present in long-range aircraft, arguably to a lesser extent.

In addition, infrastructure investment must occur to allow the uptake of new aircraft. This means that even if technologies are ready by 2029/2030, it is not clear that market introduction will happen by 2035 and that the exchange of a whole fleet will be accomplished by 2050.

The investment in new infrastructure, as well as the introduction of new aircraft is likely to lead to stranded assets. This may cause some resistance in markets especially where sources for capital to invest are tight. While this is a relevant topic, it should be noted that this is not in scope nor in the current mandate of the Clean Aviation Partnership to address this issue.

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32 OJ L 427, 30.11.2021
33 CLEAN AVIATION-GB-2021-12-16-SRIA, p. 33.

The results of Clean Aviation must contribute to and feed off the results of other partnerships, such as SESAR. Development of infrastructure and operations are just as important to achieve the Green Transition. There is also evidence from interviews that Clean Aviation is seen as a hub, bringing work across the sector together to achieve the launch of the new aircraft, thereby creating a multiplier effect that enhances its relevance.

Interviewees point out that Clean Aviation is aiming to reduce existing dependency on third-country producers in the supply chain.

The use of open calls is intended to increase competition within the European industry. While this might be challenging for effectiveness as research is more difficult to steer, it adds competitiveness which is relevant to enhance further the European industry's leadership and position in the global market.

The lower-than-first-expected budget of Clean Aviation might impact relevance. In the beginning, planning took place with a budget in mind of EUR 2.4 billion, which was downsized to EUR 1.7 billion. It inevitably led to changes in the research agenda, reducing the scope and the ability to improve the programme of work. A tight budget creates an additional challenge, as projects that cannot achieve their results or do not meet the deadlines will impact the overall ability to deliver. With higher inflation than was expected during the design, this risk increases. The budget also has to be seen in the context of overall research needed and conducted in aviation on low-carbon technology. This is estimated to be about EUR 12 billion, including Clean Aviation[34]. The other EUR 8 billion is being spent outside the control of Clean Aviation in national funding and the private sector. This means that Clean Aviation provides about a third of the required funding and is one player among others. However, it aims to bring work together and make the total relevant for the ambition of achieving climate-neutral aviation by 2050.

The calls under Clean Sky 2, while over time more focused on reducing emissions, were not forthcoming to deliver disruptive change in technology. This has been adjusted in Clean Aviation with larger topics and very clearly defined outcomes to enable the industry to take an aircraft to market by 2035. Industry and research institutions may need time to adjust to this approach. In addition, interviewees mentioned that proposals retained in the first call did not reflect the aspect of certification at a sufficient level. While they passed the evaluation threshold, follow up negotiations were required to ensure EASA was sufficiently considered in line with the legal guidance note provided under the call.

In terms of strategic development, Clean Sky had increased its focus on emission reduction throughout the programme matching the changing strategic demands. Clean Aviation overall continued this development: Call 2 is a clear continuation of Call 1 although smaller in scale.[35]

4.2. Coherence

Clean Sky 2 created strong synergies within its membership and coordination with Member States through the States Representative group. Interview results show that coherence between Clean Sky 2 and collaborative research in H2020 was steered from within the Commission. Assessing the level of coherence among partnerships and other instruments,

[34] CLEAN AVIATION-GB-2021-12-16-SRIA, p. 24.
[35] CLEAN AVIATION Second Amended Workprogramme and budget 2022 - 2023

the External Coherence Study (2022)[36] highlights the Clean Sky 2 Joint Undertaking synergy label complimentary activities' mechanism as a positive example of promoting synergies. This mechanism, which has worked well for the aviation sector, enabled Clean Sky 2 beneficiaries to introduce complimentary activities funded or eligible for support through European Structural and Investment Funds. Eighteen Memorandums of Understandings (MoUs) with national and regional authorities aligning objectives with regional strategies and Regional Strategy for Research and Innovation for Smart Specialisation (RIS3) have been signed with Member States/regions, and twelve Clean Sky Synergy Labels have been awarded to complementary activities. ESIF has supported more than fifty projects with a budget above EUR 50 million.[37] Clean Aviation continues the extensive work done in Clean Sky 2 to capitalise on synergies and complementarities with national and regional Research & Innovation programmes. It is extending its network of collaborating Member States and Regions at both strategic and operational levels.[38]

For Clean Aviation, cooperation with other partnerships and alignment with other streams of funding have been identified as crucial to achieving the overall objectives of reaching climate-neutral aviation, as the overall investment needed to transform aviation is large (see above).

In cooperation with the DG RTD "Clean Planet" Directorate, Clean Aviation has therefore launched an action plan to establish strategic cooperations on synergies with the European Aeronautics Regions/Member States.[39] The action plan builds on three key pillars: i. focusing on delivering impact on Clean Aviation objectives and its Strategic Research and Innovation Agenda; ii. leveraging substantial national/regional investments (including, for example, from Cohesion Policy Funds/ERDF) aligned to these objectives; iii. cooperating on synergies between the Regional/National Authority and the partnership.

The goal of the CAJU action plan is to establish cooperation that goes beyond what has been achieved under the predecessor programme Clean Sky 2 (CS2). Collaborations with Aeronautics Regions will be developed on the basis of a strong alignment of regional/national strategies (e.g., Smart Specialization Strategies) to Clean Aviation and joint technical roadmaps on "Net-Zero Aviation". Memoranda of Cooperation will define the terms of the collaborations, including co-designing of funding instruments at the regional/national level and implementation aspects. All regions/Member States who had signed the Memorandum of Understanding under Clean Sky 2 were invited to re-engage in cooperation under Clean Aviation. Three Memoranda of Cooperation have been signed, and several other regions/member states have expressed their interest and engagement. [40]

Coherence and synergies with national funding are assured through the States Representative Group, continuing the positive experience gained under Clean Sky 2. In addition, Clean Aviation members are involved in their national programmes. Both help to build complementarities between the different programmes and projects. Coordination of national activities has for a long time taken place by aligning them with the previous European visions and strategies (Vision 2020, Flightpath 2050, now Fly the Green Deal).

In January 2023 a Coordination and Support Action (CSA) project has been launched that further supports creating synergies with national/regional aeronautical programmes. The

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36 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 – Second interim report, p. 137

37 BMR 2022, p. 86.

38 https://clean-aviation.eu/sites/default/files/2022-11/CleanAviation-synergies-report_en.pdf [07.06.2023]

39 Indicator no. 10, BMR-Survey Data 2023 received from EC.

40 Indicator no. 10, BMR-Survey Data 2023 received from EC.

ECARE project will draw linkages between European/national/regional roadmaps and aeronautical stakeholders and co-create synergies through a pilot covering four major aeronautical European regions.

Clean Aviation aims to establish a coordinated approach with Member States on innovation for "Net-Zero Aviation" to maximize the impact of European/National/National Recovery and Resilience Plans funding. In particular, a group of Member States willing to engage in an official cooperation and technical co-roadmap has been identified to support Clean Aviation Phase 2 (2026-2031), which will be dedicated to technology maturation, integration and demonstration. Discussions with representatives of National Programmes dedicated to Aeronautics have started (e.g. Germany, France, Spain and the Netherlands).[41]

The most important partnerships for cooperation are Clean Hydrogen (regarding fuel cells as well as hydrogen as a potential fuel source) and Batt4EU, as their research results are closely connected and feed into Clean Aviation activities. With both partnerships alignment of topics has taken place on a work programme level.[42] A Memorandum of Understanding with Clean Hydrogen Joint Undertaking was signed in March 2023[43], which will strengthen the cooperation on research and innovation in hydrogen-powered aviation.

To date, the volume of activities supported by these initiatives in synergies with Clean Aviation is about EUR 109 million in EU funding[44]. Structured cooperation is also taking place with SESAR 3. Following a potential strategic alignment at the SRIA level, opportunities for aligning Work Programmes 2024-25 and launching coordinated/joint topics promoting synergies are being investigated. There is also cooperation with the "Adaptation to Climate Change" mission[45]. Outside Cluster 5, more opportunities exist with the Innovation Fund, Key Digital Technologies, the Digital Europe Programme and other research instruments related to digital technologies, the Made for Europe partnership, and the Space Initiative, especially when it concerns hydrogen-related technologies[46].

Interviewees mention several barriers to cooperation between partnerships:

- Exchange of data (to address IP rights) between projects needs to be organised by cooperation agreement: due to the open calls this is needed for projects within the same partnership, but also for cooperation among partnerships. There was no legal framework available for this so Clean Aviation created a framework which may be used as a reference by other partnerships.

- Timeframes between different partnerships' roadmaps and work programmes are not aligned. If input needed from other partnerships (e.g. Clean Hydrogen) comes too late it cannot be taken into consideration. Consultation would have needed to start much earlier to feed into their process of setting up work programmes.

- Funding for topics that have their own partnership: Partnerships are not willing to allocate funding to a topic outside their own partnership. However, Clean Aviation does not address basic research for hydrogen or topics covered in Digital Europe. These

41 Indicator no. 10, BMR-Survey Data 2023 received from EC.
42 Clean Aviation AAR 2022, p. 58-59
43 https://www.clean-hydrogen.europa.eu/document/download/59b57b91-492e-470d-af37-4649a821d9e5_en?filename=MoU%20Signed.pdf [27.02.2024]
44 Indicator no. 7a, other activities, BMR-Survey Data 2023 received from EC.
45 Indicator no. 7, BMR-Survey Data 2023 received from EC.
46 BMR 2022, p. 284

transversal partnerships need to be convinced that it is worthwhile to cooperate with Clean Aviation as a special application field and market.

Clean Aviation has supported the Commission in the definition of the aviation topics launched as part of Cluster 5 WP2021-22 and WP2023-24. From these Work Programmes, a volume of EU funding dedicated to aviation of nearly EUR 80 million is supporting activities in synergies with Clean Aviation.[47]

At the same time, views of different stakeholder groups on creating synergies with collaborative projects in the Framework programme diverge. In setting up the initial Clean Sky Programme, the European Commission and the European aeronautics industry separated the lower TRL and higher TRL aeronautics research in order to achieve higher efficiencies in the industry-led part, follow a common long-term vision, lower administrative burden, and reduce uncertainty during the evaluation processes as they entail sensitive intellectual property rights that cannot be all shared at proposal level. With the stronger impact orientation of Clean Aviation, focussing on three thrusts, the involvement of universities and research institutions is lower than it was in Clean Sky 2. Also, aviation research outside the partnerships in collaborative R&D in Horizon Europe is limited (see 5.2 above).

Some interviewees from industry suggest that a better alignment with the lower level TRL research done in Horizon Europe with Clean Aviation could make sure that research results from Horizon Europe will be fed into a pipeline and will be taken up quickly in the partnership's activities. SESAR is given as one example where both the collaborative research and the partnership research are under the partnership's management. Funding could be ringfenced for both the upstream research and the demonstrator research programme but, interviewees argue, there would be a benefit both in better allocation of money and in terms of working towards a common purpose as defined in the Strategic Innovation and Research Agenda. Another suggestion is opening the process of drafting the work programmes to participants better to meet the needs of industry and other stakeholders.[48] Several representatives from academia would like to see a dedicated funding stream within Clean Aviation for fundamental research on specific thematic topics accompanying the implementation-oriented research and technology development. Other interviewees argue that a higher share of the budget for collaborative research should be dedicated to basic research.[49] Furthermore, collaborative research should keep its independence from product development and industrial intellectual property rights in order to guarantee that European aviation explores many options that will be reviewed in future integration and demonstration programmes.

Horizon 2020 and Horizon Europe (WP2021-2023) data suggest that the collaborative aviation part of Cluster 5 and Clean Sky 2 and Clean Aviation, despite the wider objectives of the first and the focused ones of the latter, enjoy many synergies and complementarities.

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47 Indicator no. 7, BMR-Survey Data 2023 received from EC.

48 Rolls-Royce (2023): Positions and Priorities for Horizon Europe 2025-2027 and Future EU Research Framework Programmes.

49 See also Case Study "Zero Emission Aircraft" in: European Commission, Directorate-General for Research and Innovation, 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), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/744656

4.3. Efficiency

Clean Sky 2 and Clean Aviation have an overall high level of efficiency in the implementation of their processes. The administration and management of Clean Aviation build on the successful work of Clean Sky 2 with the same experienced and committed team involved. The partnership management is running smoothly, and well-established processes are starting from the regulation and the partnerships' objectives over the development of work programmes to calls, project selection procedures and grant implementation. This has led to a fast implementation of the first call taking roughly six months.

Interviewees mentioned some areas with room for improvement. Industry representatives expressed the view that the number of project officers within the programme office is small compared to the amount of public money they are responsible for, which is a heavy burden for the individuals. In an industrial context it is significantly less what a person has to manage.

Another area for improvement mentioned is reporting requirements. The challenge lies in setting the right balance between the level of detail in reporting (e.g., on KPIs) and the administrative overhead this brings. Also, the transparency on reporting requirements by central services needs to be improved according to industry representatives. Overall, the administrative burden is seen as acceptable, but some partners, particularly SMEs and airlines, would welcome additional funding as they have fewer administrative resources.

Regarding the partnership reporting processes potential for simplification is seen in engaging stakeholders to define clear objectives of the reporting process, streamline data collection, use standardized templates, focus on key performance indicators, automation of data entry and provide better guidance.[50]

In Clean Aviation, a relatively high number of agreements have been set up, with a certain level of overlap (e.g., Membership Agreement, Finance Agreement, Grant Agreement, Consortium Agreement, Cooperation Agreement). For example, an extra agreement had to be put into place to ensure data sharing between projects. This is important for the delivery of objectives in an open-call delivery mode. This and other agreements need to work for different participants, universities, SMEs, large corporates, etc. It is highlighted as an area where efficiency improvements can be made by providing legal frameworks in advance or templates that can be adapted to specific needs. In Clean Sky 2, cooperation took place within the Integrated Technology Demonstrators (ITDs), Innovative Aircraft Demonstration Platforms (IADPs) or Transverse Activities (TAs). Therefore, Clean Sky 2-wide agreements were not necessary.

Also mentioned by interviewees were IT-systems not being in place in time to function properly when needed. One of these systems is PLANES, a project management system commissioned by the partnership office to bring projects together to support the delivery of the overall programme of work. This has experienced delays. However, at this early stage in the programme it is thought not to have an impact on the project delivery. Other Joint Undertakings have shown interest in the Project Management software once complete.

A main difference between Clean Sky 2 and Clean Aviation is that there is no upfront allocation of funds anymore. In Clean Aviation, there is a totally open call mechanism for all the EUR 1.7 billion. Every organisation or group of organisations that wants to participate needs to prepare a proposal and apply, whether they are members or not, large or small. The

[50] Efficiency. BMR-Survey Data 2023 received from EC.

evaluation criteria are the same for all project proposals. Independent of this, all private members have to commit to contribute collectively a minimum of EUR 2.4bn in the form of in-kind contributions.

The ambition to reach climate-neutral aviation by 2050 needs a large investment from the public and the private sector. There is a level of complexity that has not been seen in years with step changes in efficiency and new technologies. In this regard, there are not enough resources available. The concentration and specific focus of Clean Aviation helps, but in the overall investment needed it is a small amount.

There is a risk of not having enough money to achieve the objectives. At the time of the evaluation, inflation creates an unforeseen loss in buying power, which is not being compensated. It is not clear what it will exactly entail, but it could result in cuts, e.g., it may not be possible to pursue all three thrusts. Because of the idea of demonstrating in phase 2, doing less is putting the whole concept at risk. Also, doing it later will not work if the 2050 targets are to be met. The Single Basic Act gives clear objectives that need to be met; prioritizing would mean that all adjacent activities would need to be deprioritised. It remains unclear at the moment how this could be done while still fulfilling the legal obligation coming from the single basic act. Additional funding from the EU would need to be prioritised by the parliament and the council and by the commission.

In Clean Aviation, all funding from the first two calls for proposal is allocated to Innovation Actions and CSAs. This is in line with the impact-driven approach chosen. Universities that are normally more active at lower TRL research done in RIAs are thus less involved in the partnership than in its predecessor. Interviewees from research organisations and universities highlight the risk to the future availability of qualified engineers that might result from this strategic shift: They fear that the supply chain of people who carry the knowledge of future aircraft design is at risk of being interrupted because not enough students and junior researchers are involved in the programme.

4.4. Effectiveness

To assess the overall effectiveness of the partnership, the timing of this evaluation study is not suitable. Last Clean Sky 2 projects are still running until the end of 2023, and it is, therefore too early to give an overall assessment of this partnership. The 20 projects of the first call in Clean Aviation have just started to work in late 2022 or January 2023. Therefore, the outputs and outcomes of the first Clean Aviation call are not yet visible, i.e. it is too early to assess Clean Aviation's effectiveness. Although timing affects other criteria as well this is especially relevant for effectiveness. Nevertheless, some preliminary findings shall be presented, as well as findings on the set-up of the partnership to support success.

According to the interviews, Clean Sky 2 has certainly shown that the main technological challenges have been addressed well – including in the large demonstrations. In Clean Sky 2, the whole spectrum of what is necessary for the industry was covered: systems, engines, and structures for different sizes of aircraft, from large aircraft to medium-range aircraft and for smaller aircraft. Between 2014 and 2022, in total, 478 patent applications from projects have been submitted. It largely exceeds the KPI forecast (260 patents).[51]

The Technology Evaluator, as a Transverse Activity, has been established as an independent Technology Evaluator for the entire duration of the Clean Sky 2 Joint Undertaking, i.e. until

[51] Clean Aviation AAR 2022, p. 114.

31 December 2024. A first interim global assessment has been provided in 2020. It states that substantial progress has been made in the development of the technology bricks across all platforms. Most of the concepts achieved or even exceeded their targets. The technology evaluator has considered the Clean Sky 2 programme to be on track to deliver and fully meet its environmental goals and socio-economic objectives by 2024. However, additional technologies, still under development, will be integrated by the programme's end when mature enough and will further improve the results. According to the Technology Evaluator, with its strong focus on pre-competitive technology demonstration, targeting a highly regulated aviation market characterised by extraordinarily long lifecycles, Clean Sky 2 achievements will become noticeable within the global fleet only after 2035, the earliest entry into service being 2030 for the most mature mainliner aircraft concepts.[52]

The Partnership has commissioned its study to assess its socio-economic effects. The authors of this independent study on the socioeconomic impact of Clean Sky 2 estimated an economic benefit of EUR 8.5bn from the Clean Sky 2 programme. This includes benefits to the aviation industry and related industries such as airports, tourism etc. and are estimated as the direct contribution of funding, R&D activity within the supply chain and worker spending impacts. In addition, EUR 320bn of environmental benefits arising from CO_2 and NO_X reductions by 2050 and further health benefits, including from a reduction in noise, are expected, if Clean Sky 2 technologies are incorporated into the global aircraft fleet.[53]

In total, 1,678 scientific publications (only peer-reviewed and technical papers) have been published between 2014 – 2022, stemming from projects in Clean Sky 2. This exceeds the KPI target by 20%.[54] The following section summarises the results of a bibliometric analysis of Clean Sky 2 research output from 2014 – 2021 (see Annex 8.2.2). They are compared here with the data for Societal Challenge 4–- Smart, Green and Integrated Transport (SC4) in H2020.

In the bibliometric data on research outcomes, Clean Sky 2 stands out for several strengths. These include (see Annex 8.2.2):

- A percentage share of 22% of Clean Sky 2 publications were written as academic-private co-publications.
- Clean Sky 2 publications were three times more often among highly cited publications at the 5% threshold within their subfield and year than the world level.
- A proportion of 67% of Clean Sky 2 publications were available under an open-access modality (open access).
- Clean Sky 2 publications included a 23% share of authorships by Associated Countries (including the UK).

Clean Sky 2 publications recorded comparable achievements to those of other SC4 projects e.g. regarding cross-disciplinarity, share of international co-publications and most dimensions of the citation impact. However, there are also some weaknesses regarding the research outputs and outcomes. Clean Sky 2 publications recorded lower levels of online dissemination and attention regarding mentions in journalistic pieces and social media. No

52 Clean Sky Technology Evaluator: First Global Assessment 2020. Technical Report. p. 94 and 98.
53 Roland Berger: Towards climate neutral aviation - An independent study on the Socioeconomic Impact of Clean Sky 2. p.4.
54 Clean Aviation AAR 2022, p. 113.

Clean Sky 2 publications have been mentioned in online policy-related documentation so far. Only a limited number of publications benefitted from the participation of a female researcher.

Many of the results of Clean Sky 1 and 2 are now feeding into Clean Aviation, which was TRL 5 or 6 at the component level. They are picked up by Clean Aviation and are being enhanced and customised for the new challenges in thrusts of Clean Aviation. Whereas the Clean Sky projects were not that big in terms of volume (on average, half the size of the Clean Aviation projects in the first call), they showed results about what is possible, also at lower TRL. And the next step was to cluster them into a new aircraft.

At the beginning of Clean Aviation, the partners have worked out exactly what to do to achieve the set objectives. If those partners could then execute exactly what they had planned for, one would expect that the set objectives would be met. Founding members and the associated members committed to the SRIA (at strategic and financial levels). Clean Aviation is closely working with EASA in all projects thereby allowing certification processes to start early on.

Projects need to be working for the industrial partners as well. They have their internal procedures. By integrating partners from other industries and SMEs, cross-learning and out-of-the-box thinking are supported, according to interviewees.

Findings on the prior performances of those researchers selected for funding in Clean Aviation (see Annex 8.2.3.) show that their past research had a higher share of academic-private co-publications at 14% (compared to 7% at EU27+UK overall level) and was thematically highly aligned with the SDGs (59% for Clean Aviation against 48% at EU27+UK overall level). On the other hand, Clean Aviation researchers'' track record on cross-disciplinarity can be characterised as weak: A share of 5% of 2017-2021 publications by Clean Aviation investigators were highly multidisciplinary (compared to 9% for the lowest benchmark), and 8% were highly interdisciplinary (compared to 13% in the highest benchmark). This data also shows that aviation research is a highly specialised subject area. Also, the average share of authors that were women in Clean Aviation researchers' prior publications was much below the benchmarks at 14%, against 33% in the next closest benchmark (EU27+UK industry).

Considering citation impact achievements as well as the findings already presented, Clean Aviation researchers' track may be characterised as oriented towards scientific excellence above other dimensions. Past research by Clean Aviation investigators performed much above the benchmarks on the three citation impact indicators. For example, 30% of this past research fell amongst the most highly cited publications of their subfield and year, against 18% for EU27+UK overall.

However, past performance is subject to change, and the ambitions of the partnership to improve some of the practices of supported researchers will most likely prevent replication of what has come before. These findings, therefore, can help focus on areas that might require particular improvement and/or monitoring.

In Clean Aviation, efficiency indicators, including time-to-pay, time-to-grant and call topic success rates, are monitored continuously with positive results for those mentioned.[55] There are KPIs for impact monitoring that are linked to each project (see Annex 8.1.2). There is also

[55] Clean Aviation AAR 2022, p.85, 121, 124.

a tool, the impact monitor. The added value of the discussions with the Commission was that the same KPIs were discussed, selected, and shared across the industry.

Whereas Clean Sky 2 had a common overall work plan, in Clean Aviation, every project had to write a similar (standardised) proposal document with milestones, objectives, deliverables, IP, etc. It brings rigour and transparency. That is an important difference in the programme, how objectives are being set and monitored. The annual review will be project by project and not by the broad strands of Clean Sky 2 anymore.

But it is important to remember that it is research which inherently includes a risk of failure. Clean Aviation has a risk mitigation plan for the high-risk technology. This risk mitigation plan is presented as part of each project.

Some of the demonstrators that were planned in Clean Sky 2 have been delayed and will be finished in Clean Aviation. Research takes longer sometimes. An influencing factor for the delays was certainly the COVID-19 pandemic, where, for example, laboratories could not be used, and personal interactions and travel were limited.

However, in the EU Partnership programmes, two elements impact the effectiveness of how the programme will reach the set objectives. One element is the open-call principle, and the other element is the involvement of independent evaluators. Both can impact the effectiveness positively or negatively, but both are out of the control of the initial partners that designed the programme. Because of the open call principle, it is not possible to plan and detail who will implement the projects in which way and in which consortium constellation. In the first call of Clean Aviation, some evaluators made suggestions to remove full work packages from proposed projects or certain elements at lower TRL; however the partners deemed those as necessary. Eventually, the partners will reach their goals, however much less efficiently because of those recommended reductions of scope.

Another challenge is that the programme is cut into two parts. After Phase 1, those technologies to be taken forward need to be selected. But it does not mean that the other technologies are not good or would not need further investment. This selection will also have an impact on the expected outcome of the whole programme and on how the addressed technologies find their way to the market.

4.5. EU added value

While Clean Sky 2 brought together the aviation community along the value chain behind the objective to reduce emissions, Clean Aviation is now expecting to be able to take this community into the demonstration phase of the regional and/or short to medium-range passenger low-emission aircraft.

Aviation is a global business. The US and others in Asia are strong players. Interviewees have highlighted that speaking as a European industry gives individual European players more weight in this market than they otherwise would have. Clean Aviation is, in fact, seen as a hub for developments around low or no-emission air traffic. This means that at the global level, European R&I can “punch above its weight”.

Interviewees have made similar arguments with respect to certification. The critical mass that is represented in the Clean Aviation partnership can work effectively with EASA, which is represented at the global level, easing the path of international certification. According to interviews, the cooperation with EASA, including the Memorandum of Cooperation signed by

EASA and Clean Aviation, means that the process of certification can be shortened as EASA is always updated on developments in the Joint Undertaking.

Interviewees have also identified that European partnerships enhance diversity of thinking. One party highlighted that while companies conducting national research in each member state could hire people from different backgrounds this was still a different way of working than a truly European project where different working cultures were contributing to a single objective. The partnership approach adds, therefore increased creativity and productivity of the researchers, potentially enabling solutions which would not have been found on a purely national level.

Working on projects across Europe and, in many cases, with third-country partners creates career opportunities for researchers. This is also enabled by the approach of EU Joint Undertakings such as Clean Sky 2 and Clean Aviation.

4.6. Additionality

In Clean Sky 2, the EU contribution shall be up to EUR 1.755 bn (2014-2024) according to the regulation. This should be supplemented by a minimum of EUR 2.194 bn to be contributed by the members (leaders and Core partners).[56] In Clean Aviation overall, the EUR 1.7bn of EU funding is matched by at least EUR 2.4 bn from private partners (2022-2031).[57]

In-kind contributions are made up of In-kind Contributions from implementing Additional Activities (IKAA) and In-kind Contributions from Operational Projects (IKOP). IKAA include activities such as

- development and testing of component technologies,
- development of accompanying manufacturing methods and techniques,
- development of supporting technologies, e.g. research and technology development of architectures, technology bricks and other enablers for systems and airframes; and
- aircraft architecture design process.

Reported IKOP amounts to EUR 986.2 million (2014-2022), of which EUR 829.2 million are certified. IKAA value of EUR 1.27 billion reported includes a total amount of EUR 1.03 billion fully certified by the members' external auditors and validated by the Governing Board for the period 2014-2021.[58]Assuming that the current amount will be fully validated and the current trend will be constant for the remaining two years of the H2020 programme, the private members will exceed the overall minimum EUR 2.155 billion in-kind contribution obligation

[56] COUNCIL REGULATION (EU) No 558/2014 of 6 May 2014 establishing the Clean Sky 2 Joint Undertaking. Article 3 and 4.
[57] Council Regulation (EU) 2021/2085 of 19 November 2021, Article 10 and 11.
[58] Clean Aviation AAR 2022, p. 72.

as required by the Council Regulation.[59] According to BMR data, in the predecessor partnership EUR 2.343 billion have been contributed.[60]

The first Clean Aviation projects started in 2023, and therefore, no IKOP/IKAA have been reported for 2022.[61] By industry partners EUR 470 million was committed in-kind by August 2023, About 20% of the target for the whole duration of Clean Aviation (EUR 2400 million in total).[62] The target is to create at least a leverage of 1.5 to achieve the EUR 2400 million of in-kind contribution by the end of the programme as required under the Single Basic Act. Further leverage will be sought from national programmes and other research funding as part of an innovation architecture spanning the major national R&I programmes in Member States and Associated Countries. The total amount of investment referring to the total additional activities triggered by Clean Aviation is EUR 875 million so far.[63]

The direct leverage in this report represents the additional funds from third parties, public or private, that the EU project budget funds have mobilized (see Annex 8.2.4). In Clean Aviation, the total eligible costs amounted to EUR 901.4 million (June 2023) for Call 1. The EU funding rate for all action types was 72.5%. The direct leverage factor for innovation actions – the only action type represented in Clean Aviation – was 0.378. The leverage from the Business Enterprise Sector was 0.507 and, thereby considerably higher than for other organisations.

4.7. Directionality

While the last few projects of Clean Sky 2 are still being completed, overall projects have achieved the intended results, and so has the partnership Clean Sky 2 as well. This means that a significant contribution has been made to the vision. Clean Aviation builds on these successes.

The spectrum of development in Clean Aviation is much narrower than in Clean Sky 2. Planning has started from the required results in 2050 and 2035, respectively, identifying which milestones need to be met when to meet targets and address the European and global challenges. As discussed above this bears its risks, including that a delayed or missing contribution by a project can put progress at risk. The direct link between the R&I activity in Clean Aviation and its impact also requires a positive reaction from the market. Airlines and infrastructure need to be ready for the Clean Aviation results.

Clean Aviation is focussed on the development of those aircraft which are used most and with rising trend leading to increasing emissions. These are regional, medium-range-sized aircraft. Results can feed into other future developments, for example, long-range if successful, especially as some of the engineering challenges are harder to meet on those aircraft which fly shorter distances as most pressure is applied during take-off and landing.

As such it can be acknowledged that Clean Aviation contributes with all of its expenditures to climate objectives.

Clean Aviation is also a key instrument for Europe to strengthen its strategic autonomy and technological sovereignty in the aviation sector, in particular in light of the global competition

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59 Clean Aviation AAR 2022, p. 73.
60 Indicator no. 1, BMR-Survey Data 2023 received from EC.
61 Clean Aviation AAR 2022, p. 74.
62 Indicator no. 1, BMR-Survey Data 2023 received from EC.
63 Indicator no. 2, BMR Survey Data 2023 received from EC.

(USA, China). Aviation is a strategically important sector for Europe. Despite the current economic crisis, global air transport over the long term is expected to grow by around 5% annually until 2030. In this context, it is Europe's aviation sector that needs to remain competitive while transforming towards a climate-neutral sector in line with the EU Green Deal (EGD) objectives.[64]

4.8. International positioning and visibility

Aviation is an international industry, components and systems come from all over the world and are embedded in aircraft of different manufacturers. The private members of Clean Sky 2/ Clean Aviation have a clear visibility outside of Europe, being internationally leading players.

The partnership's dissemination and coordination activities are not only taking place at the European level but also further on an international level. A high share of the partnership budget invested into activities, tasks and work-packages is aimed at reaching out to create linkages and establish collaboration with international organisations and entities in non-EU countries[65]. Clean Aviation considers itself the hub for aviation research in Europe. The partnership is perceived as a very prominent player at the international level. For example, Clean Aviation and its members featured prominently at the annual Science and Technology Forum and Exposition of the American Institute of Aeronautics and Astronautics, the largest event in the world for aerospace research, development, and technology. The partnership management gets invitations from organisations like the International Civil Aviation Organization (ICAO), the United Nations specialised agency working on international civil aviation Standards and Recommended Practices and Policies, to provide their opinion on future research and action needs. Through the integration of the European Union Aviation Safety Agency (EASA) in the projects, there is also a close link with its United States counterpart, the Federal Aviation Administration (FAA), and other comparable international organisations.

Coordination and dissemination are also required to ensure the market and infrastructure are ready to receive new aircraft by 2035. As part of the Alliance for Zero-Emission Aviation (AZEA), they are promoting to start preparing the market for the entry into service of zero-emission aircraft today.

4.9. Transparency & Openness

In Clean Sky 2, first, the setup of membership and participation was different to Clean Aviation because the leaders were listed in the regulation[66] . Then Clean Sky 2 went through several calls only for core partners and affiliates. Since this provided a particular incentive, the membership grew very fast to beyond 90 members.

For the development of the SRIA, Clean Aviation had all members of the partnership included and even reached out outside the membership. Basically, everybody who was interested in contributing was invited. Smaller groups, such as the SMEs without a pan-European umbrella organisation or universities, had a harder time exerting influence, but they were included in the process.

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64 Thematic focus of the BMR 2024. BMR-Survey Data 2023 received from EC.
65 Indicator no. 4, BMR-Survey Data 2023 received from EC.
66 Annex II to Regulation n° (EU) No 558/2014

For Clean Aviation, there was an ideal that it would be open for new actors and non-aviation companies, too, bringing in different perspectives. It is, therefore, one of the KPIs of Clean Aviation. Interviewees pointed out that some companies are more open to this than others because of project budget considerations. The Clean Aviation JU has some outreach. It has been trying to connect, but participation in projects is, in most cases, achieved on a one-to-one basis. With a more rigorous approach, there could be more different actors (e.g. oil and hydrogen industry, airlines, and technology developers).

The partnership is open to members who have headquarters outside of the EU (e.g. in the US) but have significant engineering and manufacturing resources in Europe. This openness to also participate as members of the Governing Board was positively highlighted by these companies.

As the results of the first Clean Aviation call have shown there is a good mix of participants. Big companies take the biggest share (68% of funding) and account for about half of the participants (49%). 14% of all (single) participants are SMEs. They receive only 6% of the funding.[67] There have been 52 newcomers (out of 244 single participants) who have never been involved in Clean Aviation / Clean Sky calls. A newcomer is defined as a legal entity awarded for the first time as a beneficiary of a grant in the 1st Clean Aviation call since the start of Clean Sky (Clean Sky and Clean Sky 2) and who is not an affiliated entity to Clean Aviation Members or Clean Sky/Clean Sky 2 Leaders. A third of those newcomers are SMEs. The first call attracted two research institutes and 8 universities as newcomers.[68]

According to the interviews nobody is missing in the partnership. This is possible due to the Open Call principle where each project can bring the necessary partners (JU Member or not) to fulfil the required actions. There are ample project partners who are not members. Non-members' participation in the 1st call amounted to 49% of all participation. A share of 82% of the funding has been allocated to members even though there was no allocated budget for them. Clean Aviation's impact-driven approach means that the range of topics is narrower than in Clean Sky 2. In addition, the higher TRL research agenda favours companies in general and large companies in particular, to the disadvantage of universities and research institutions. With all major players in the aviation industry being among the members of Clean Aviation this explains this effect.

Interviewees also noticed that, in the consortia currently being formed for the second call, there are companies, universities and research institutes not seen before in the field. It means that Clean Aviation has probably managed to broaden the scope a little.

While looking for inclusiveness, the partnership still has to look for excellence and complementarity among participants. The members of the partnership have promised to deliver impact based on the SRIA. Therefore, as highlighted by the interviewees, it is important to make sure that SMEs and other participants are the excellent ones, not just there to fill in statistics.

Regarding gender balance, the share of female participation, female coordinators and female expert advisors and evaluators are monitored and presented in the Annual Activity Reports of Clean Aviation, as was the case for Clean Sky 2. The Annual Activity Report shows that 9% of experts identified in the first call were women (in 2021 and 2022), the female participation rate was just under 27%, unchanged from 2021, while only just under 17% of

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67 CLEAN AVIATION – First Call for Proposals – statistics. March 2023. p. 3.
68 CLEAN AVIATION – First Call for Proposals – statistics. March 2023. p. 6.

project coordinators were women (in 2021 and 2022).[69] This is well below the proportion of women employed in science and technology in the EU in 2022 (52%) and the overall proportion of women among scientists and engineers (41%)[70].

4.10. Phasing out preparedness

The transition from Clean Sky 2 to Clean Aviation started about two years before Clean Aviation was formally started, and a lot of effort was put into setting up the successor. Interviewees noted that progress was held up due to restrictive budget rules which prohibit any spending before a formal Council agreement of the Joint Undertaking.

It is a legal obligation for all Joint Undertakings to adopt a plan for the phasing out of the partnership from Horizon Europe funding by the end of 2023. At the time of writing this report, a phasing-out strategy was not available. However, a preliminary plan has been adopted by the Clean Aviation Governing Board in December 2023[71] as required by the SBA and preparatory measures are on the way to update the plan by the end of 2024.

5. Conclusions

In conclusion, the following points with respect to the Clean Sky 2/Clean Aviation Joint Undertaking merit highlighting.

There is a step change from Clean Sky 2 to Clean Aviation with its concentration on aircraft development that makes it possible to introduce new aircraft by 2035, the timeline having been calculated backwards from the objective of climate-neutral aviation by 2050. This means a paradigm shift in thinking and working. It led to cuts in the topics covered and a shift to mainly high TRL research.

If the challenge of the Green Transition is to be taken seriously in aviation, then the industry must be part of the solution. It is already a considerable accomplishment to have succeeded in bringing all leading companies into the JU. There are clear benefits from this cooperation, including the shortening of communication links and the avoidance of duplication. Taking the societal challenge seriously, there is no alternative way; having the industry behind the overall objectives is an accomplishment in itself, and there are clear benefits to be expected by leapfrogging a whole generation of technology for the European industry as well as society at large. By involving EASA early on, a conscious effort is being made to bring forward certification processes and make up for the time needed.

But there are also major risks involved:

- There is no room for error: timelines are tight and interconnected. The connections between projects need to be well managed.

- Even if technologies are ready by 2029/2030, it is not clear that market introduction will happen by 2035 and that exchange of a whole fleet will be accomplished by 2050. A lot

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69 Clean Aviation, Consolidated Annual Activity Report, 2022
70 Eurostat. https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20230602-1
71 https://clean-aviation.eu/sites/default/files/2024-01/CAJU-GB-Writ%20proc%202023-12%20Phasing%20out%20plan_signed.pdf [27.02.2024]

of stakeholders still need to be convinced. A lot of investment (in infrastructure, amongst others) still needs to be done.

Change from pre-allocated funds for members in Clean Sky 2 to open calls in Clean Aviation is being criticised by those making the contributions. It seems too early to form a conclusive opinion on this, but currently, it looks like it seems to work. There is still interest in becoming a member because shaping the research agenda and work programmes gives a head start in writing successful proposals. 80% of the funding in the first call has been allocated to members even though they had to compete in the open call. This is a higher share than they received in Clean Sky 2.

Even though it is not within the responsibility of Clean Aviation, the evaluation results indicate that the strategic shift to an impact-driven approach might have unintended consequences outside of the partnership's direct sphere of influence. Due to more partnerships in Cluster 5 Destination 5/6, budgets for lower TRL research have been reduced. This has repercussions for the aviation research landscape in Europe. With H2020, countries were able to build aviation eco-systems that do not have a long history in aviation, thus broadening the landscape and tapping into the competencies of more countries (visible in Case Study "Zero emission aircraft" performed in phase 1 of this evaluation study). There is a risk of losing these capacities, with knock-on effects for future generations of young talent. This is even more important as there are fewer universities involved in Clean Aviation already posing a risk of a gap in young engineers and academics familiar with the new technologies.

6. Lessons Learned & Recommendations

All in all, the following transferable lessons learned can be drawn, and recommendations for further programming can be given, albeit preliminary to some extent.

- Clean Aviation was able to build on the experience of Clean Sky 2, making it possible to have a quick start and short time for the first projects being launched. The Programme Office benefits from a lean management structure and committed and experienced staff.

- Learning from other industries is important, and integrating companies from different sectors, specifically SMEs, has been shown to facilitate this. A next step is to strengthen openness and exchange between transversal and sector-specific partnerships.

- Integration of EASA from the start in all projects seems to be a promising approach to shorten certification processes.

- A close eye needs to be kept on budgets: Due to the high interdependencies in the approach, there is no room to manoeuvre in response to the high inflation rate. If all three thrusts have promising results, it might be necessary to allocate additional funds.

- To have a better understanding of private and public investments, IKAA reports should disclose individual shares of private members and national co-funding for Clean Aviation.

- An assessment of whether and how Clean Aviation works should be done in due time, both in terms of technological results towards impact and governance structures. This evaluation is too early to give a conclusive statement. If Clean Aviation is continued in a tried and tested form a smooth transition is to be expected.

- If major changes are deemed to be necessary (i.e. regarding governance or a shift of the research agenda), a transition process should be foreseen. It needs administrative capacities, and funds should be available at an early stage within the current budget for the preparation of the successor programme.

- With more connections to other partnerships and other funding mechanisms there is a higher need for alignment and legal cooperation frameworks. Central services of the Commission need to be involved early on, helping to shape agreements that are fit for purpose. This also applies to other partnerships in competitive industries.

- Market uptake is of high importance and should be – as started – tackled from the beginning. A strategy should be developed for what needs to be done for aircraft manufacturers to take up the technology, for airlines to buy the aircraft, for airports to prepare for necessary investments, etc. Maybe additional activities need to be started around this topic.

- Following this line of argument, closer cooperation with SESAR could be beneficial to address ATM-related issues with respect to Clean Aviation's objectives early on.

- Links to the collaborative research in Horizon Europe should be strengthened in Clean Aviation to ensure systematic uptake of research results. There should be, on the other side, no influence of the partnership's research agenda and needs on the collaborative research in the framework programme.

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8. Annexes

8.1. Supplementary evidence: Background to the initiative Supplementary evidence: Implementation state of play

8.1.1. List of Clean Aviation members

Founding members

1. Aciturri Aeronáutica S.L.U.
2. Aernnova Aerospace SAU
3. Airbus SE
4. Centro Italiano Ricerche Aerospaziali SCPA (CIRA)
5. Dassault Aviation SA
6. Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
7. Fokker Technologies Holding BV
8. Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V.
9. GE Avio S.r.l.
10. GKN Aerospace
11. Honeywell International s.r.o.
12. Industria de Turbo Propulsores S.A.U.
13. Leonardo SpA
14. Liebherr-Aerospace & Transportation SAS
15. Lufthansa Technik AG
16. Łukasiewicz Research Network – Institute of Aviation
17. MTU Aero Engines AG
18. National Institute for Aerospace Research (INCAS)
19. Office National d'Etudes et de Recherches Aérospatiales (ONERA)
20. Piaggio Aero Industries
21. Pipistrel Vertical Solutions d.o.o.

22. Raytheon
23. Rolls-Royce Deutschland Ltd & Co KG1
24. Safran
25. Stichting Koninklijk Netherlands Lucht- en Ruimtevaartcentrum (NLR)
26. Thales AVS France SAS
27. University of Patras

Associated members

1. Aeromechs srl (as of Dec 2023)
2. AIMEN Technology Centre (as of Dec 2023)
3. ASCENDANCE FLIGHT TECHNOLOGIES (as of Dec 2023)
4. Asco Industries N.V. (as of Dec 2023)
5. ATR G.I.E. (as of Dec 2023)
6. CAPGEMINI Represented by Capgemini Service SAS (as of Dec 2023)
7. COSTRUZIONI AERONAUTICHE TECNAM SPA
8. Fokker Next Gen N.V. (as of Dec 2023)
9. FUNDACION TECNALIA RESEARCH & INNOVATION
10. H2FLY GmbH (as of Dec 2023)
11. HELLENIC AEROSPACE INDUSTRY SA
12. INEGI (as of Dec 2023)
13. IRT Saint Exupéry (as of Dec 2023)
14. ISRAEL AEROSPACE INDUSTRIES LTD
15. NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY (NTNU)
16. POLITECNICO DI TORINO
17. PowerCell Sweden AB (as of Dec 2023)
18. SIEMENS INDUSTRY SOFTWARE NV
19. SINTEF AS / SINTEF ENERGI AS

20. Skylife Engineering S.L. (as of Dec 2023)
21. SOLiTHOR BV (as of Dec 2023)
22. SOLVAY SA
23. TECHNISCHE UNIVERSITAET BRAUNSCHWEIG
24. TECHNISCHE UNIVERSITEIT DELFT
25. TEST-FUCHS GmbH (as of Dec 2023)
26. The University of Nottingham (as of Dec 2023)
27. TUSAŞ (Turkish Aerospace) (as of Dec 2023)
28. Universidad Politécnica de Madrid (as of Dec 2023)
29. UNIVERSITAET STUTTGART
30. Von Karman Institute for Fluid Dynamics (as of Dec 2023)
31. VZLU - Czech Aerospace Research Centre (as of Dec 2023)
32. ZeroAvia UK (as of Dec 2023)

8.1.2. Key Performance Indicators of Clean Aviation

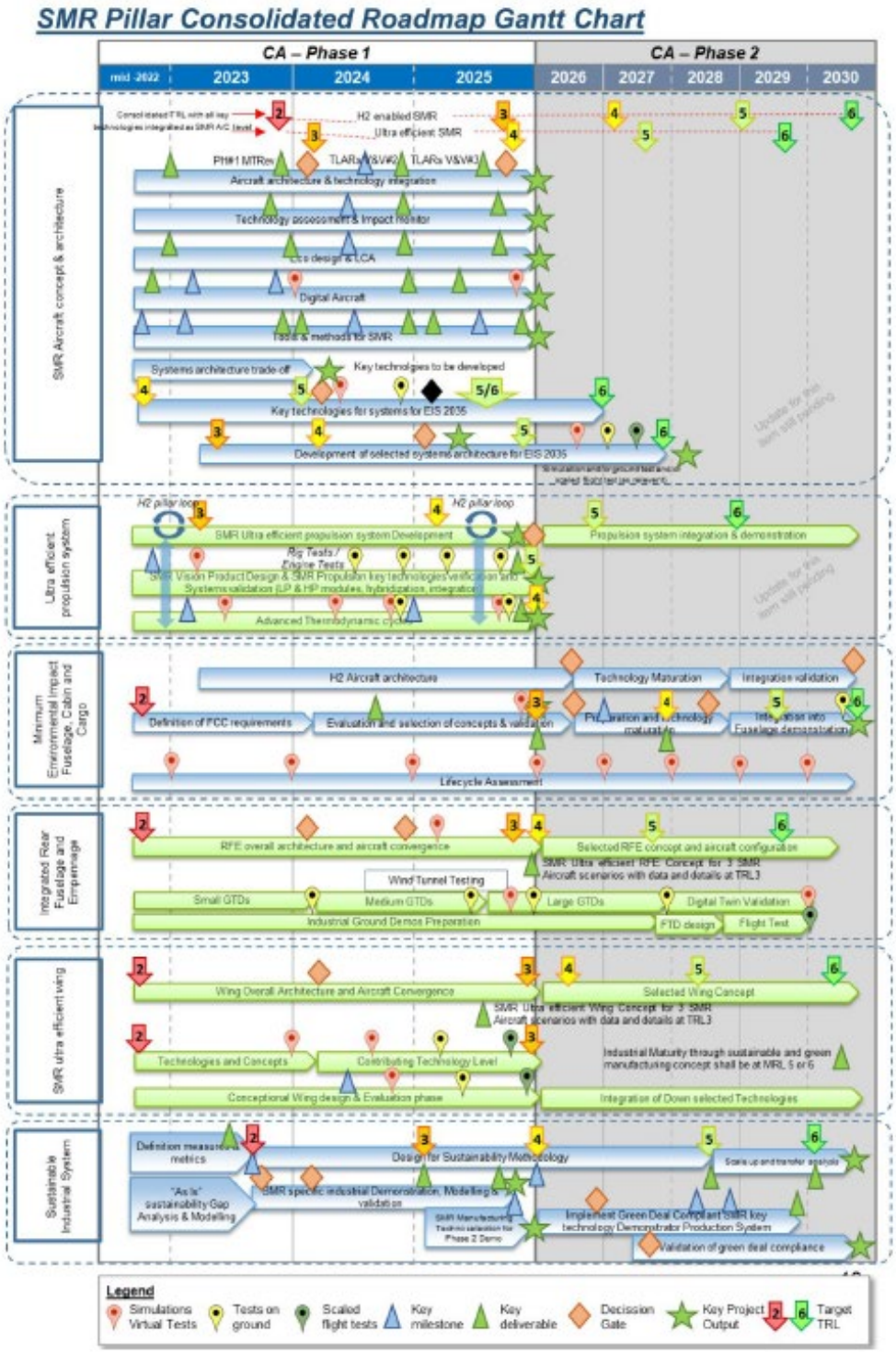
Figure 9: Clean Aviation Key Performance Indicators

KPI NAME	UNIT OF MEASUREMENT	BASELINE	TARGET 2023	TARGET 2025	TARGET 2027	TARGET >2027
RESOURCES (INPUT), PROCESSES AND ACTIVITIES						
Newcomers (cross-over from non-aeronautical domains)	# and funding (euro)	N/A	TBD	TBD	TBD	TBD
Country participation (EU 27 and associated countries)	#	H2020 evaluation for first year level	TBD	TBD	TBD	TBD
Collaboration and Synergies • within Horizon Europe • within other EU Budget • with national programmes • regional programmes [RIS3]	# and funding leveraged	H2020 evaluation or first year level	 TBD TBD TBD >20 regions >€25 m	 TBD TBD TBD >25 regions >€50 m	 TBD TBD TBD >25 regions >€75 m	@ end of programme: >€100 m[1] >25 regions >€100 m
Leverage effect from private sector contribution	# (defined as private sector contribution divided by the EU contribution)	H2020 evaluation or first year level	TBD	>0.41	>1.0	>1.41 (@ end of programme)
OUTCOMES						
Technology Readiness Levels	Critical technologies reaching TRL6 by 2030	H2020 evaluation or first year level	0	0	TBD	TBD
Demonstrated CO_2 emissions reduction potential • from SMR [2] • from HER [3]	%	2020 state-of-the-art technology	 N/A N/A	 N/A N/A	 N/A N/A	(> 2035) >30 % >50 %
IMPACTS						
Net GHG emissions reduction	%	compared to 2020 state-of-the-art	N/A	N/A	N/A	>30 % (>2035)
Market deployment of CA solutions	# solutions (manufacturing ready)	TBD	Minimum 2 new aircraft (order by 2030, delivery by 2035)			
Fleet renewal	% (of the global fleet)	TBD	TBD	TBD	TBD	75 % (>2050)
Time To Market Reduction (TTMR)	%	2020 certification processes	TBD	TBD	TBD	30 % (2030)
Cost reduction of certification	%	2020 certification processes	TBD	TBD	TBD	30 % (2030)
EU aeronautics leadership	Global market share in leading technologies	2020 market share	EU aeronautics maintains its 2020 global market share			

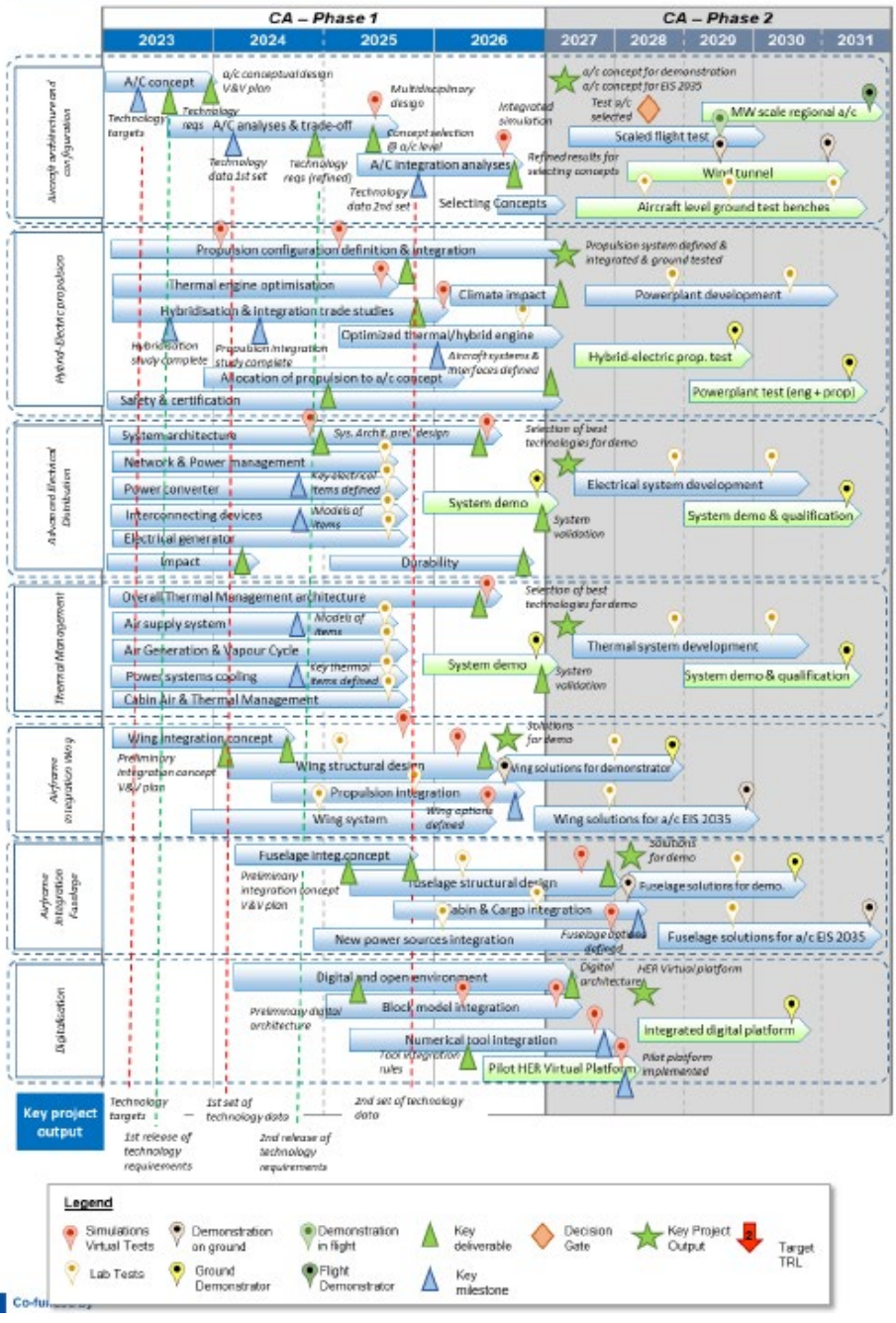
[1] with 3 JUs, 2 Cluster R&I WP areas
[2] SMR: Short-Medium Range aircraft
[3] HER: Hybrid Electric Regional aircraft

Source: BMR 2022, p. 283

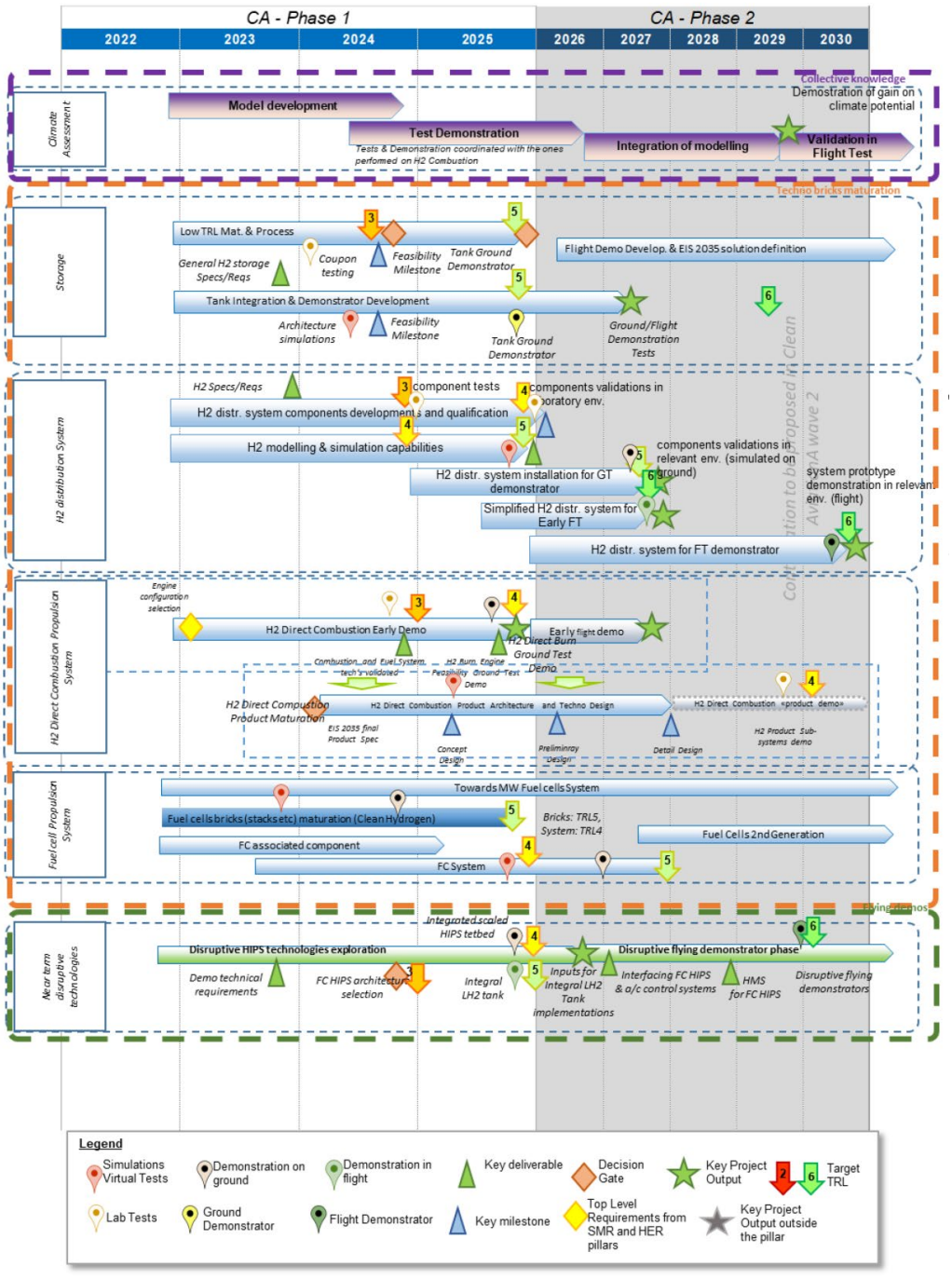
8.1.3. Building blocks of Clean Aviation and their roadmap



HER Pillar Consolidated Roadmap Gantt Chart



H2 Pillar Consolidated Roadmap Gantt Chart



Source: Clean Aviation, Joint Undertaking, AMENDED WORK PROGRAMME and BUDGET 2022-2023

8.2. Supplementary evidence: Results

8.2.1. Women Participation

The table below includes 2 distinct metrics of women participation.

1. Average share of female participants: first computed the share of women participants in each project, then averaged across projects.

2. Share female participations: This is the number of female participations (i.e., researchers are counted more than once if they participate in different projects) divided by the total participations.

Table 13: Women participation in partnerships

Partnership	Nb projects	Nb participations (organizations)	Nb participations (researchers)	Average share female participants	Share female participations	Nb female participations	Nb male participations	Nb non-binary participations
ER (Shift2Rail successor)	6	452	152	15%	15%	23	129	0
Batt4EU	50	702	626	25%	25%	155	470	1
Clean Steel	10	102	96	24%	24%	23	73	0
2ZERO	20	420	363	18%	17%	63	300	0
CLEANH2	45	498	417	23%	22%	93	324	0
Built4People	6	132	113	30%	29%	33	79	1
CLEAN-AVIATION	20	492	440	18%	16%	70	370	0
CCAM	18	348	310	24%	22%	69	241	0
CBE	21	293	274	39%	39%	108	166	0
SESAR 3	15	108	103	25%	24%	25	78	0
ZEWT	26	334	306	14%	13%	40	266	0

Data on gender as available in CORDA is subject to a few limitations:

- Data at grant table was only available for “main contacts” (i.e., 1 person per project), with no gender information. We then took the researchers from the proposal table. As such, compositions of teams may have changed from proposal to projects.

- There is no trivial way of identifying real researchers among the persons included in this table. Visual inspection indicates that most of them were actual researchers (i.e., not administrative roles only).

- By comparing the number of participations (based on organisations) with the number of participations (based on researchers), it is clear that only a small part of researchers involved in the projects are included in CORDA.

The above table is based on the most recent CORDA provided to us.

8.2.2. Bibliometric Analysis

In the bibliometric data on research outcomes, Clean Sky 2 stands out for several strengths. These include:

- A percentage share of 22% of Clean Sky 2 publications were written as academic-private co-publications, against 17% in SC4 and 13% at the EU27 overall level.

- Clean Sky 2 publications were three times more often amongst highly cited publications at the 5% threshold within their subfield and year than world level, compared to almost two times the world level in SC4 and in EU27 more generally.

- A proportion of 67% of Clean Sky 2 publications were available under an open access modality (open access), against 62% at the SC4 level and 44% at the EU27 overall level.

- Clean Sky 2 publications included a 23% share of authorships by Associated Countries (including the UK), against 17% at the SC4 level and 3% at the EU27 overall level.

Clean Sky 2 publications recorded comparable achievements to those of other SC4 projects on the following dimensions:

- Proportion of publications written as international co-publications with at least one lead author (first, senior, or corresponding) from a Third Country

- Average number of countries found in publications' affiliations, per publication

- Average shares of authorships in a given publication by researchers from EU27, ERA, or Third Countries

- Cross-disciplinarity of publications (with the sole exception of highly interdisciplinary papers, although this sole exception should not distract from the overall conclusion)

- Share of authorships taken up by female researchers, although this share could arguably be considered problematic for both Clean Sky 2 and SC4 publications, where paper-level averages are of 11% and 14%, respectively

- Most dimensions of citation impact including on the citation distribution index (CDI), which captures the average citation impact performance in a pool of papers without giving undue weight to high citation outliers

- Clean Sky 2 publications also recorded comparable citation impact performances as SC4 publications on the average of relative citations (ARC, an average score but with some potential influence from high citation outliers); and the share of publications amongst the top 10% most cited publications of their subfield and year (HCP10%).

However, there are also some weaknesses regarding the research outputs and outcomes:

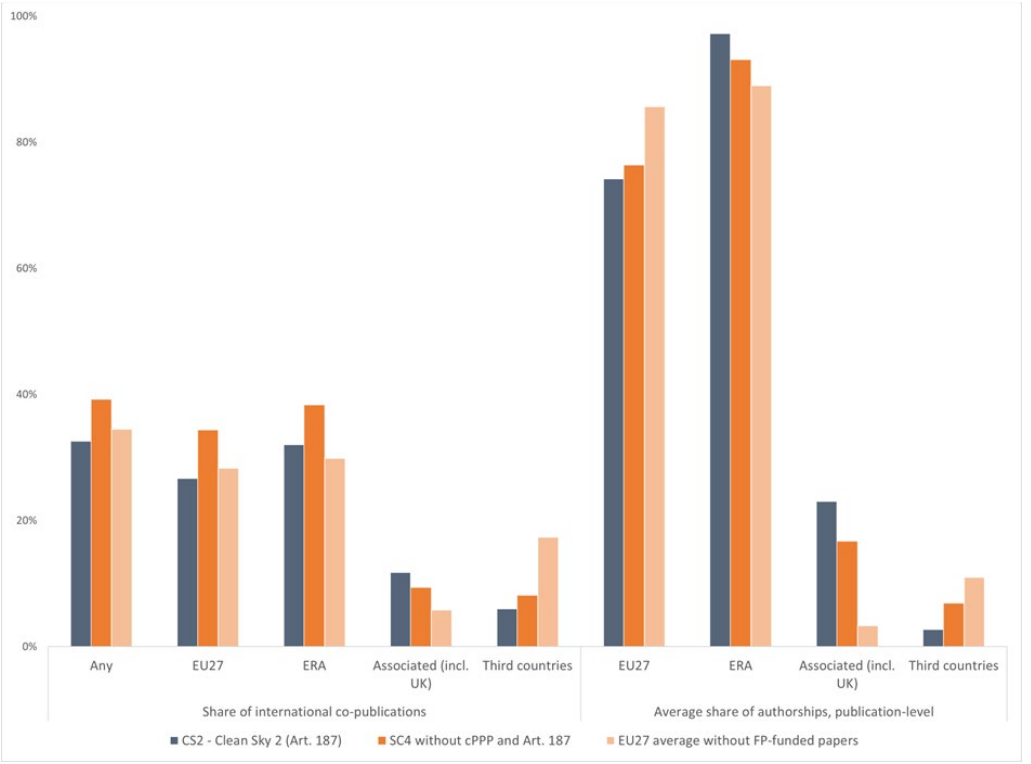
- A proportion of 33% of Clean Sky 2 publications were written as international co-publications. This amounted to a small decrease against the SC4 baseline of 39%. This result was roughly on par with the EU27 average in the thematic area (35%). The decrease was driven by drops in international co-publications amongst EU27 countries (27% against 33% of papers in the baseline), whereas international co-publications with Third countries (6% in Clean Sky 2 publications against 8% in the SC4 baseline). Note that Clean Sky 2 publications', just like all partnership and SC4 publications, are at a major lag to the EU27 average on co-publication with Third Countries (with the average at 17%).

- A share of only 29% of Clean Sky 2 publications benefitted from the participation of at least one female researcher, against 37% in the SC4 baseline and 41% in the EU27 average.

- Clean Sky 2 publications recorded lower levels of online dissemination and attention on all altmetrics dimensions (mentions in journalistic pieces, on Facebook, on Twitter and on Wikipedia). To take one example, the share of Clean Sky 2 publications mentioned in journalistic pieces is half (0.4) that expected from the world level, while baseline SC4 publications were mentioned in such news items more than two times more the expected level (2.3). On average, the share of relevant EU27 publications mentioned in journalistic items was 50% higher than expected (1.5).

- No Clean Sky 2 publications have been mentioned in online policy-related documentation so far, against a reference level that is four times (4.2) the world level for other SC4 publications. The EU27 average on this dimension is three times the world level. It should be noted that mentions of journal publications in policy-related documentation optimally requires citation windows of 4 years, which has also not elapsed here. Therefore, these findings are preliminary and subject to change.

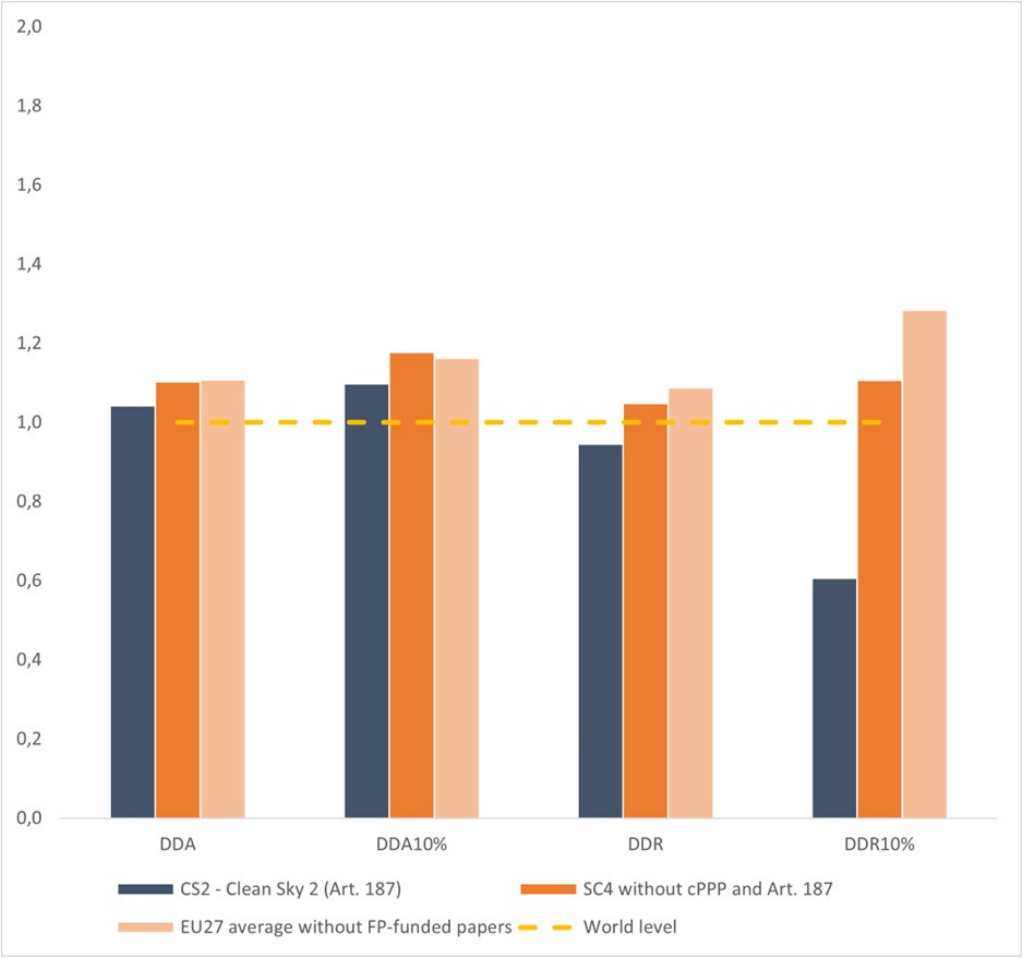
Figure 10: Clean Sky 2: International co-publication profiles (2014-2021)



Note: Share of international co-publications with at least one first, last, or corresponding author from the aggregate of interest. Share of authorships: average publication-level share of authorships held by researchers from the country aggregate of interest.

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

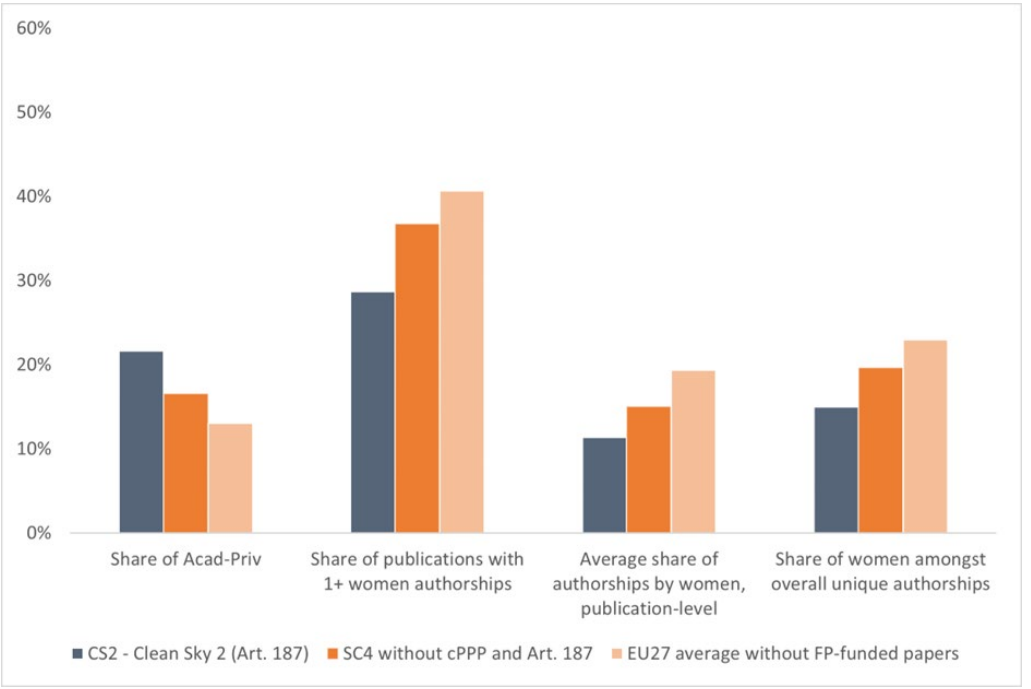
Figure 11: Clean Sky 2: Cross-disciplinarity of publications (2014-2021)



Note: DDA: diversity in disciplinary background of authors, capturing the relative collaborative multidisciplinarity of authors from different backgrounds working together. DDA10%: share of publications falling in 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.

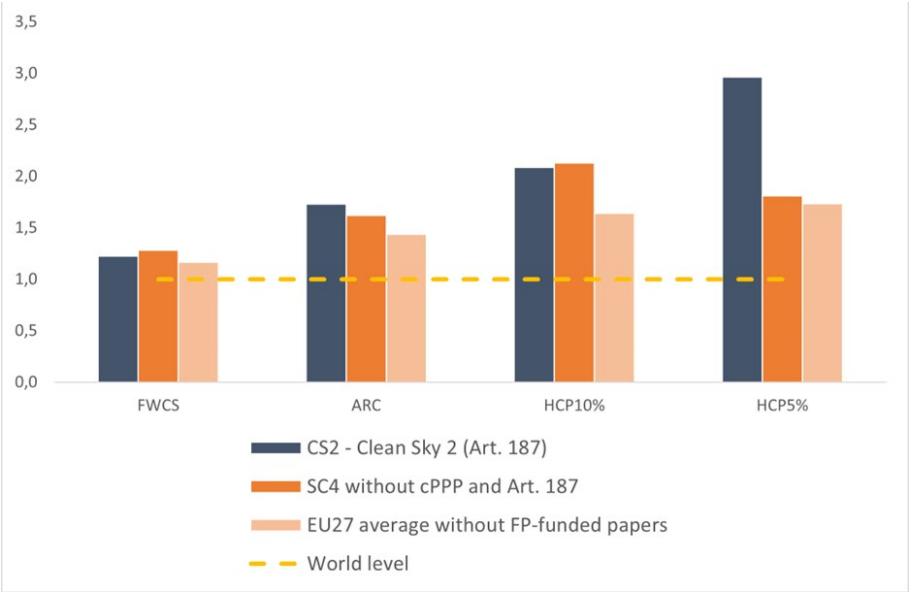
Source: Science-Metrix/Elsevier using data from Scopus (Elsevier) and eCorda

Figure 12: Clean Sky 2: Academic-private co-publications and gender equity in authorship (2014-2021)



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

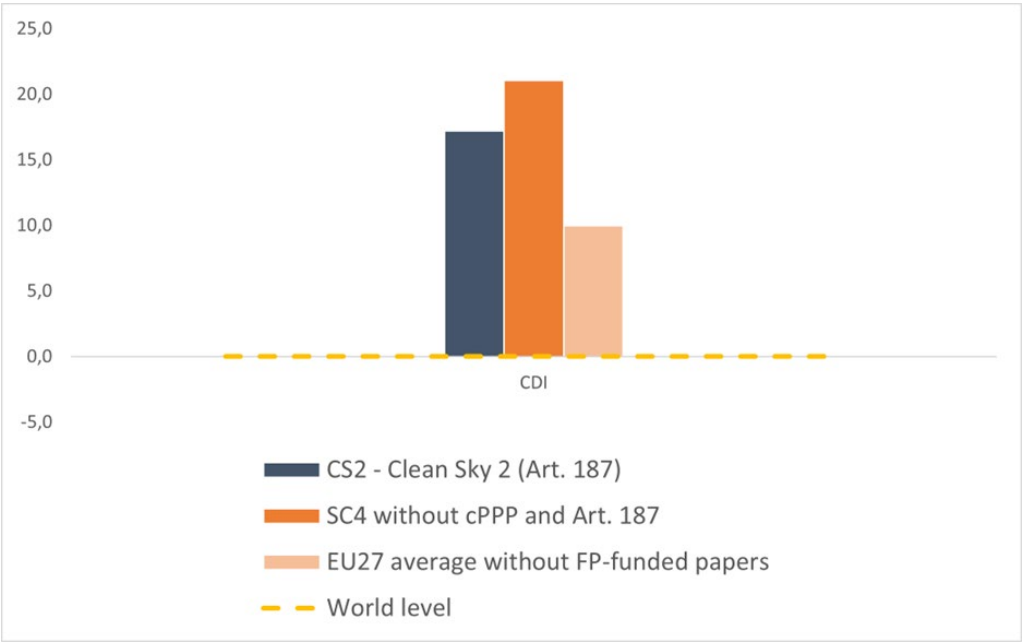
Figure 13: Clean Sky 2: Cite Score and citation impact profiles (2014-2021)



Note: FWCS: Field Weighted Cite Score. ARC: average of relative citations. HCP: Highly cited publications.

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

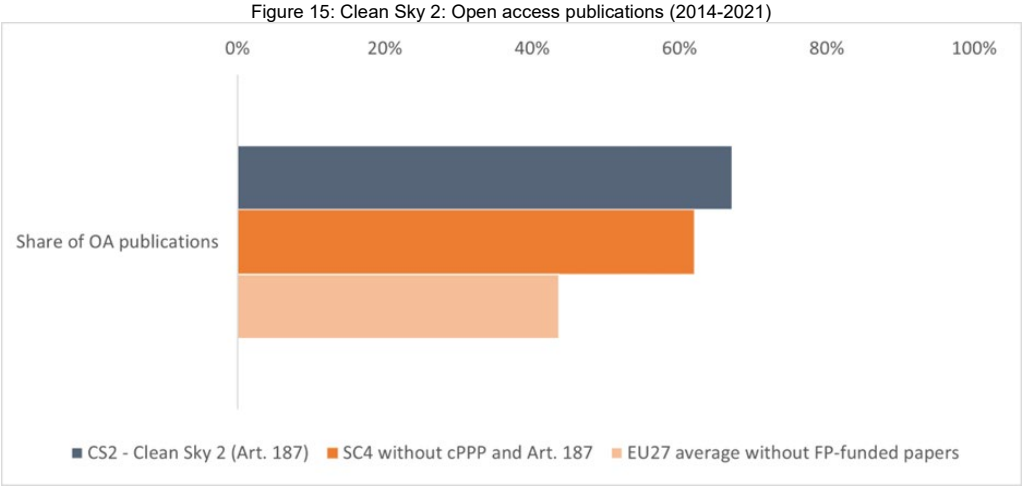
Figure 14: Clean Sky 2: Citation distribution index (2014-2021)



Note: CDI: citation distribution index.

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

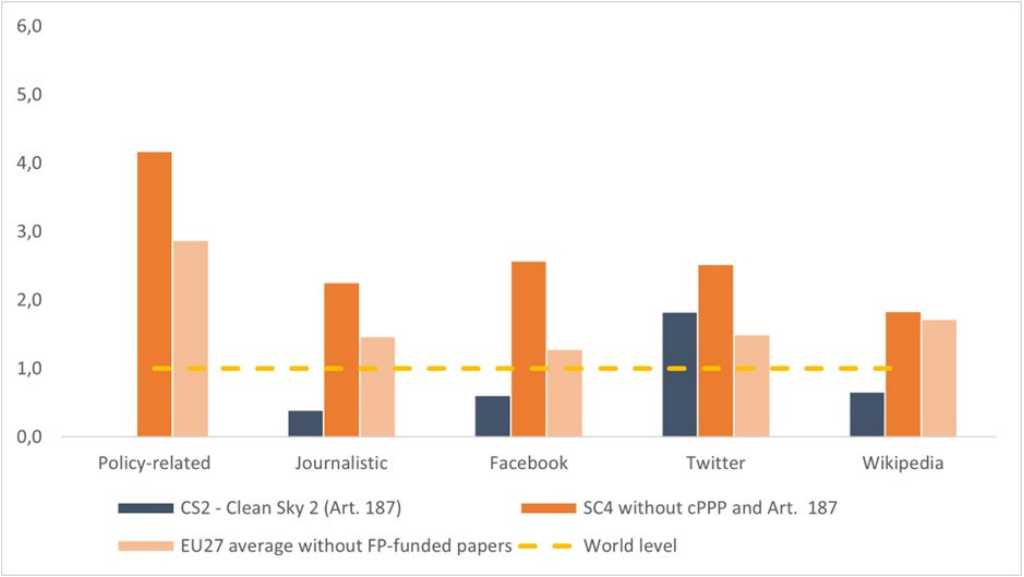
Figure 15: Clean Sky 2: Open access publications (2014-2021)



Note: OA: open access.

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

Figure 16: Clean Sky 2: Policy-related, and altmetrics mentions profiles (2014-2021)



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

8.2.3. Partnership Calibre Analysis

Notes on interpretation of the partnership calibre analysis

The KIP monitoring framework recommends that scientific outputs such as journal publications or citations towards these publications be evaluated no earlier than two years after the supported projects of interest have been completed. On this basis, as of fall 2023, it is not appropriate, nor is even the necessary data even available, to conduct a bibliometrics evaluation exercise of Horizon Europe journal-publication-mediated scientific outputs.

To measure instead enabling factors of Horizon Europe effectiveness, a so-called calibre analysis can be performed on the prior scientific achievements of researchers involved in projects selected for Horizon Europe funding. Cluster 4 researchers' prior publications (from 2017 to 2021) were retrieved to establish their track records on dimensions such as academic-private co-publication, cross-disciplinarity, or scientific excellence (proxied through citation impact), among others. It was hypothesised that Horizon Europe funding competitions should select, for example, researchers with past experience in conducting cross-disciplinary research, as a mechanism to increase the likelihood that societal impacts will be realised from supported projects.

One important limitation of this approach is that past achievements are no guarantee of continued performance; and that successful funding instruments may in fact succeed in greatly changing researchers' past practices towards improved practices. Therefore, the calibre analysis does not obviate the need for future monitoring and evaluation, but it can provide a baseline against which to measure future developments, and help focus future on areas that might require particular improvement and/or monitoring.

The calibre analysis of researchers now active in Cluster 4 destinations, interventions areas, action types, or partnerships, has been performed using the same set of indicators as used

in phase 1 of this evaluation. They have been applied to the set of 2017-2021 publications by researchers identified as now active in Cluster 5 and Cluster 6 projects, including partnership projects.

To help differentiate these past achievements by Cluster 5 and Cluster 6 researchers, benchmarks have been assembled as follows:

- EU27+UK overall: all 2017-2021 GT publications with at least one EU27 or UK affiliation, but excluding FP-supported articles
- LERU: all 2017-2021 GT publications with at least one affiliation with an institution that is part of the League of European Research Universities, but excluding FP-supported articles
- EU27+UK industry: all 2017-2021 GT publications with at least one EU27 or UK private sector affiliation, but excluding FP-supported articles.

By definition, EU27+UK industry researchers have a strong academic-private co-publication score. Therefore, the benchmark should not be used on this specific indicator.

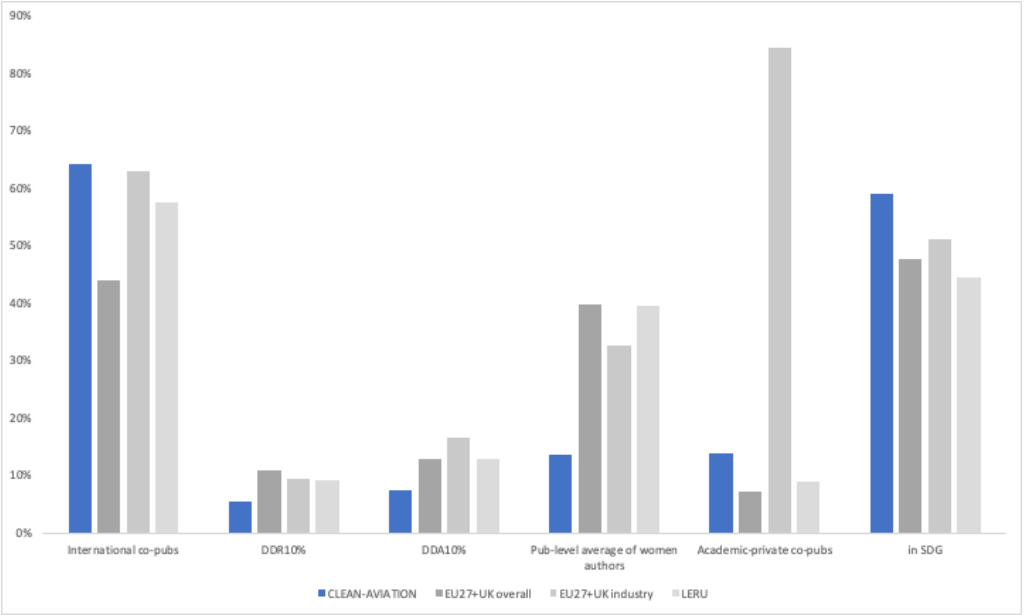
For the three altmetric indicators used here (citation from online policy-related documents, Wikipedia mentions, and trade and journalistic news outlets mentions), a new normalisation method is being rolled out as part of Phase 2 work. Indeed, for each altmetric finding, a custom synthetic world level (often referred to as the "expected") is provided. Synthetic world levels are the average level of publications with one or more altmetrics mentions in equivalent (in terms of disciplinary distribution) global reference sets. This normalisation methods differ from normalisation methods commonly used for citation impact indicators to better control for effects associated with sparser altmetrics signal.

Pre- Horizon Europe track record of Clean Aviation researchers on dimensions that are enabling factors for project effectiveness

Clean Aviation researchers' track record on team diversity and societal readiness

- Past research by Clean Aviation investigators included a high share of academic-private co-publications at 14%. This compared to 9% at LERU level and 7% at EU27+UK overall level.
- A share of 59% of Clean Aviation researchers' 2017-2021 publications were thematically aligned with the SDGs. This was well above the benchmarking range (45%-51%).
- A share 5% of 2017-2021 publications by Clean Aviation investigators were highly multidisciplinary (compared to 9% for the lowest benchmark), and 8% were highly interdisciplinary (compared to 13% in the highest benchmark). Clean Aviation researchers' track record on cross-disciplinarity can be characterised as weak on this basis.
- The average share of authors that were women in Clean Aviation researchers' prior publications was much below the benchmarks at 14%, against 33% in the next closest benchmark (EU27+UK industry).

Figure 17: Pre- Horizon Europe track record of Clean Aviation researchers on selected dimensions of diversity and societal readiness of research teams (2017-2021)

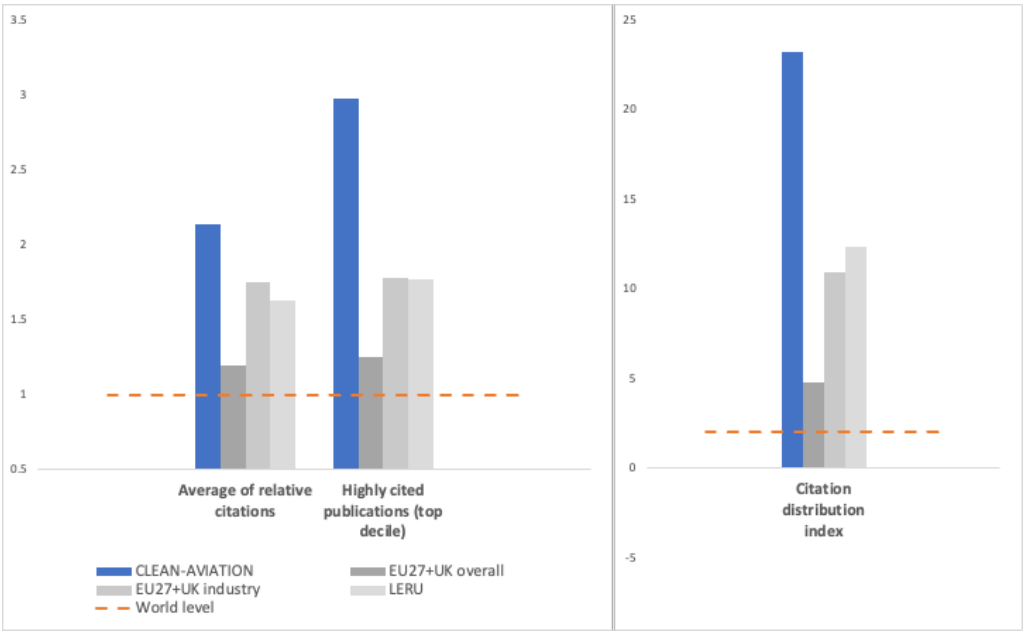


Note: DDR10%: share of publications amongst the top decile of publications with most disciplinary diversity in references (i.e., most interdisciplinary) in their subfield, year, and document type. DDA10%: share of publications amongst the top decile of publications with most disciplinary diversity in authorships (i.e., most multidisciplinary) in their subfield, year, and document type. Source: Scopus, NamSor and eCorda databases processed by Science-Metrix

Clean Aviation researchers' track record on citation impact as proxy for scientific excellence and leadership

- Considering citation impact achievements as well as the findings on diversity and societal readiness already presented, Clean Aviation researchers' track may be characterised as oriented towards scientific excellence above other dimensions. past research by clean aviation investigators performed much above the benchmarks on the three citation impact indicators. For example, 30% (or 3.0 in indexed form as in the figure below) of this past research fell amongst the most highly cited publications of their subfield and year, against 18% for LERU researchers.

Figure 18: Pre- Horizon Europe track record of Clean Aviation researchers on citation impact (2017-2021)



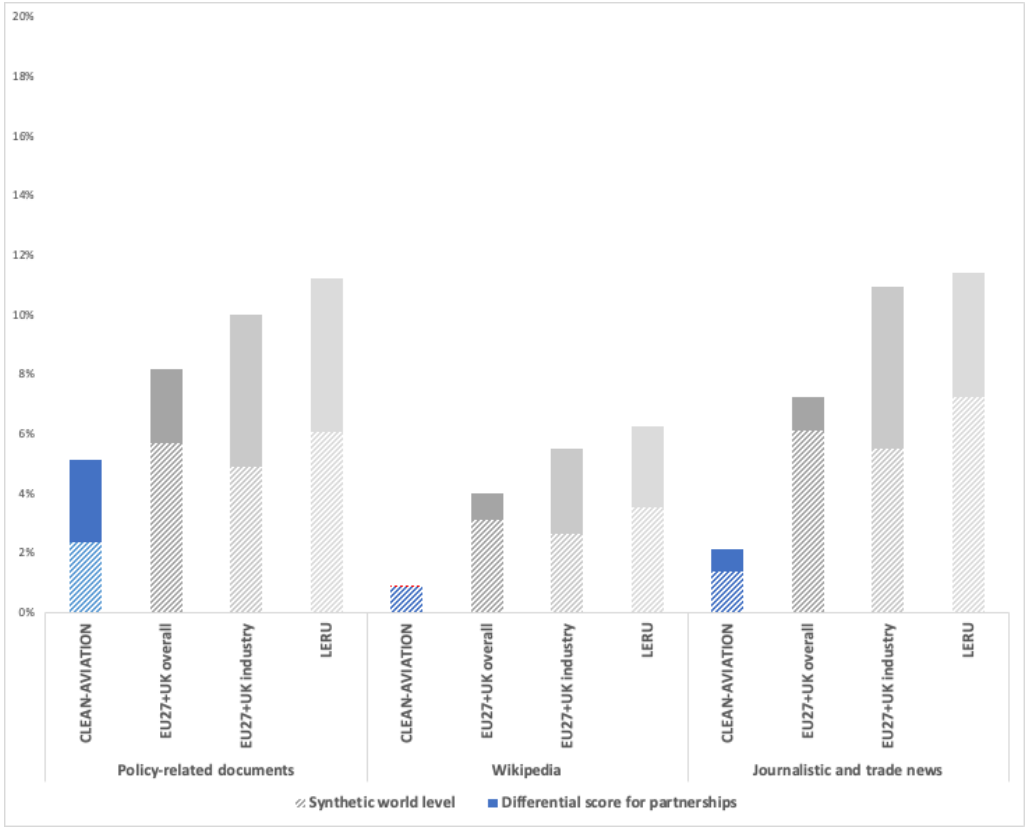
Source: Scopus and eCorda databases processed by Science-Metrix

Clean Aviation researchers' track record on online dissemination capacity, including OA and online policy-related uptake:

- Past research by Clean Aviation investigators saw some traction in online policy-related documents, at a level comparable to the top end of the benchmark range, 2.8 percentage points above an expected level of 2.3%.

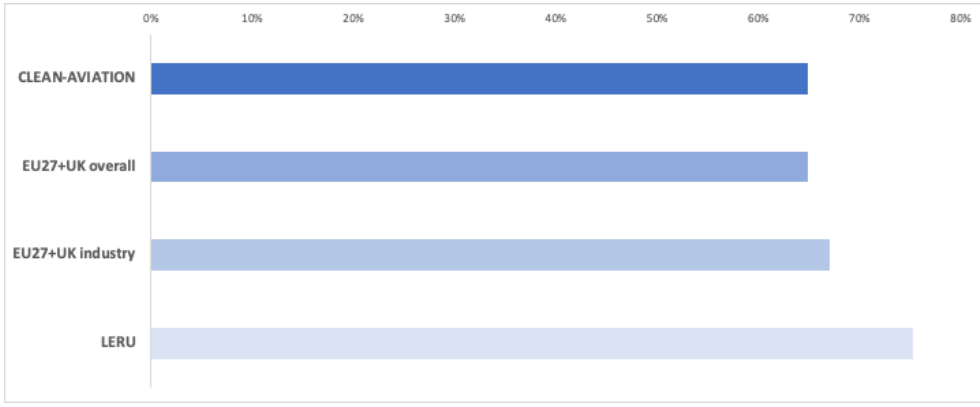
- Clean Aviation investigators' track record on Wikipedia mention was weak, falling below the benchmarking range, 0.1 percentage points under the expected level of 0.9%.

Figure 19: Pre- Horizon Europe track record of Clean Aviation researchers on selected online dissemination dimensions (2017-2021)



Note: Synthetic world levels are the average level of publications with one or more altmetrics mentions in equivalent (in terms of disciplinary distribution) global reference sets. Comparisons with benchmarks should be made on the differential scores (represented by the full bar sections as opposed to the stripped sections representing the synthetic world level). Differential scores are presented in red where they are negative, that is, below the expected world level. Source: Scopus, PlumX, Overton and eCorda databases processed by Science-Metrix

Figure 20: Pre- Horizon Europe track record of Clean Aviation researchers on OA publishing (2017-2021)



Source: Scopus, Unpaywall and eCorda databases processed by Science-Metrix

8.2.4. Leverage factor

The direct leverage in this report represents the additional funds from third parties, public or private that have been mobilized by the EU project budget funds.

Figure 21: Horizon Europe: Leverage factor of partnership projects

Partnership	org_type_groups	Total Eligible Cost (EUR milion)				Funding Rate (EU Contr/Total Cost)				Direct Leverage Factor* (1/Funding_Rate)-1			
		All action types	CSA	IA	RIA	All action types	CSA	IA	RIA	All action types	CSA	IA	RIA
2ZERO	any org type	231.3	3.8	131.2	96.4	0.817	0.973	0.701	0.968	0.224	0.027	0.426	0.033
	PRC only	153.0	1.4	96.2	55.4	0.725	0.971	0.592	0.948	0.380	0.030	0.689	0.054
Batt4EU	any org type	298.7	10.0	31.4	257.3	0.958	0.978	0.744	0.983	0.044	0.023	0.343	0.017
	PRC only	127.8	3.0	17.9	106.8	0.921	0.972	0.583	0.977	0.086	0.028	0.716	0.024
Built4People	any org type	57.3	1.2	56.1	0.0	0.757	0.854	0.755	N/A	0.321	0.171	0.325	N/A
	PRC only	31.3	0.3	31.0	0.0	0.588	1.000	0.583	N/A	0.701	0.000	0.714	N/A
CBE	any org type	148.4	2.9	98.6	47.0	0.783	1.000	0.698	0.949	0.277	0.000	0.433	0.053
	PRC only	89.6	1.4	68.5	19.7	0.658	1.000	0.582	0.899	0.520	0.000	0.719	0.113
CCAM	any org type	184.1	0.0	118.7	65.4	0.819	N/A	0.733	0.976	0.220	N/A	0.364	0.025
	PRC only	92.0	0.0	64.1	27.8	0.688	N/A	0.577	0.943	0.454	N/A	0.734	0.060
CLEAN-AVIATION	any org type	901.4	0.7	900.7	0.0	0.725	1.000	0.725	N/A	0.378	0.000	0.379	N/A
	PRC only	734.1	0.2	733.9	0.0	0.663	1.000	0.663	N/A	0.507	0.000	0.507	N/A
CLEANH2	any org type	423.2	2.1	270.8	150.4	0.641	0.993	0.469	0.945	0.561	0.007	1.133	0.058
	PRC only	334.3	0.4	250.5	83.4	0.548	1.000	0.427	0.908	0.825	0.000	1.340	0.101
ER (Shift2Rail successor)	any org type	315.9	0.0	315.9	0.0	0.736	N/A	0.736	N/A	0.359	N/A	0.359	N/A
	PRC only	278.1	0.0	278.1	0.0	0.700	N/A	0.700	N/A	0.429	N/A	0.429	N/A
SESAR 3	any org type	29.1	3.8	6.6	18.7	0.785	0.880	0.576	0.840	0.274	0.136	0.737	0.191
	PRC only	12.4	2.4	3.6	6.4	0.866	1.000	0.688	0.916	0.155	0.000	0.454	0.092
ZEWT	any org type	222.2	0.5	129.9	91.8	0.757	1.000	0.599	0.979	0.321	0.000	0.668	0.021
	PRC only	173.7	0.1	107.2	66.4	0.690	1.000	0.515	0.973	0.449	0.000	0.944	0.027

Source: CORDA (version from June/2023), except data on ER (Shift2Rail successor) which was obtained from the Horizon Dashboard (this data was incomplete on CORDA)
NOTES:
Data on EU contribution and Total Eligible Cost was extrated from CORDA (table participants)
Direct Leverage (not displayed) corresponds to the difference between Total Eligible Costs and EU Contributions
Funding Rate is the share of EU contributions on the Total Eligible Cost
Direct Leverage Factor corresponds to (Direct Leverage)/(EU Contribution)

Source: CORDA

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This evaluation report is part of the interim evaluation of Horizon Europe activities related to the Green Transition. It presents the assessment of the Institutionalised European Partnership Clean Aviation Joint Undertaking (CAJU) against the evaluation criteria of relevance, coherence, efficiency, effectiveness, EU added value, additionality, directionality, international positioning and visibility, transparency and openness as well as phasing out preparedness. The evaluation of the partnership is based upon a mixed-method approach including quantitative and qualitative data analysis.

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