European Commission

Scaling up innovative technologies for climate neutrality

Mapping of EU demonstration projects in energy-intensive industries

Research and Innovation

Scaling up innovative technologies for climate neutrality

European Commission
Directorate-General for Research and Innovation
Directorate E - Prosperity
Unit E.1 - Industrial research, innovation & investment agendas
Contact Pauline Sentis
Email *RTD-TF-CLIMATE-NEUTRAL-INDUSTRIES-2030@ec.europa.eu*
pauline.sentis@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

Manuscript completed in May 2023
First edition

PDF ISBN 978-92-68-03466-8 doi:10.2777/926968 KI-09-23-224-EN-N

Luxembourg: Publications Office of the European Union, 2023

EUROPEAN COMMISSION

Scaling up innovative technologies for climate neutrality

Mapping of EU demonstration projects in energy-intensive industries

2023 Directorate-General for Research and Innovation

Contents

FOREWORD

During all the unprecedented disruptions of recent years, we kept our firm commitment to the European Green Deal. In record time, we adapted our European policies to the need to achieve climate neutrality in less than 30 years. RePowerEU, the Recovery and Resilience Facility, the Renewable Energy Directive, the revision of the EU Emissions Trading System, the revision of the State aid framework and lately, the adoption of a Net-Zero Industry Act – all work together towards this one goal, breaking our dependencies on fossil fuels.

The steel, chemicals, cement, and other energy-intensive industries are important for all our industrial value chains in Europe. At the same time, we know that they account for 17% of greenhouse gas emissions in the EU (2019). These industries need to become large users of renewable energies and green hydrogen to substitute the use of fossil resources – and they need to do if fast. Therefore, a broader and faster roll-out and scale-up of innovative climate-neutral technologies is paramount – the sooner, the better for the climate, and for Europe.

For energy-intensive industries, energy efficiency and emissions reductions are a particular challenge. Many of the most promising technologies are still in development stages. They need significant investments to reach production at scale by 2030 at the latest. This is the way to go – so we have a duty as policymakers to take appropriate measures for the green transition.

This report provides an overview of the key technologies developed and demonstrated in over 180 installations, enabling energy-intensive industries to reduce their greenhouse gas emissions. It presents the demonstrators' technological maturity, the sectors addressed, and their location in European countries. It sends a signal to industry, public and private investors, national governments and managing authorities to support and increase investments that will turn our ambition into a planet-compatible reality.

ACKNOWLEDGEMENTS

This report has been published within the context of the new European Research Area (ERA) by the Directorate-General for Research and Innovation (DG RTD) — Directorate E, Prosperity.

The project was coordinated under the leadership of Angelo Wille and Doris Schröcker (respectively, Deputy Head and Head of DG RTD.E1 Industrial Research, Innovation & Investment Agendas). This document was produced by Angelo Wille and Pauline Sentis (Policy Officer at DG RTD.E1).

The overview of demonstrators is the result of the work of an inter-service task force, led by DG RTD and the Directorates-General for Climate Action (DG CLIMA) and Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) and guided by the Deputy Directors-General Joanna Drake, Clara de la Torre and Maive Rute. With regard to the implementation of the Task Force's mandate, we are thankful to Philip Hawkins and Nikos Pantalos respectively, for the cooperation.

This report is the outcome of strong collaboration of services across and beyond the Commission, involving colleagues from the Joint Research Centre (JRC), the Directorates-General for Energy (DG ENER), for Regional Policy (DG REGIO), for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW), for Climate Action (DG CLIMA), for Environment (DG ENV), and the European Health and Digital Executive Agency (HADEA). In particular, we are grateful to Garbine Guiu Etxeberria, Antonio Ferrandez Garcia and Dominique Planchon in RTD.E3 'Industrial transformation'; to Alessandra Colli in RTD.C3 'Low emission future industries'; to Luca Giovannelli in RTD.C1 'Clean energy transition'; to Lucia Fernandez Macia in HADEA; to Piero Carlo Dos Reis and Willem Van Ierland in DG CLIMA; to Eric Aries, Jose Moya, Simon Gutierrez Alonso and Alain Marmier in the JRC; to Eric Lecomte in DG ENER, and to Luis Galiano Bastarrica in DG REGIO, for their contributions to the overview of demonstrators.

Adrian Marica, Florence Roger, Constantin Belu and Alex Talacchi in DG RTD.E1 strongly contributed to the completion of this overview.

Peter Dröll, Director for Prosperity in DG RTD, and Andrea Ceglia, made substantial contributions to the review of this work. Jürgen Tiedje, Sofie Norager and Marcela McAndrew in DG RTD.E3 also contributed to the review of the draft report.

We are grateful to Suvi Vuorinen, Balint Peter Linder, Valentine Barelier and Martina Daly (DG RTD) for their support in the administration and communications activities.

MAPPING OF EU DEMONSTRATION PROJECTS FOR CLIMATE NEUTRALITY IN ENERGY-INTENSIVE INDUSTRIES

1. INTRODUCTION

1.1. Policy context

The EU must drastically accelerate the clean energy transition and quickly reduce its dependence on fossil fuels. With **REPowerEU**[1], the EU has set out its plans to achieve these goals by diversifying energy imports and reducing gas consumption. Emergency measures were taken in 2022: the Council Regulations on **'Coordinated demand-reduction measures for gas[2]'** and on **'Emergency intervention to address high energy prices[3]'** were adopted, and the EU decided in 2023 to increase the ambition of its renewables and energy efficiency targets and of the measures in the **Renewable Energy Directive and Energy Efficiency Directive**. Indeed, the unprovoked invasion of Russia into Ukraine has further increased the urgency of diverting from fossil fuels to reach the **Green Deal** objective of climate neutrality by 2050 and an intermediate target of reducing greenhouse gas emissions by at least 55% below 1990 levels by 2030, as laid down in the **European Climate Law**[4]. On 18 and 25 April 2023 respectively, the Parliament and the Council adopted the revision of the EU Emissions Trading System (ETS), which currently covers all energy-intensive sectors as listed in Annex I of the ETS Directive[5], introducing steeper annual emissions reduction rates, and a two-step reduction of the overall emissions cap – thus incentivising energy-intensive industrial installations to reduce their emissions more rapidly.

All these policies considerably strengthen the business case for a faster deployment in EU industries of new technologies that will improve energy efficiency and for the switch from fossil to renewable energy sources, in particular through electrification and the use of renewable hydrogen.

Energy-intensive industries accounted for 17% of overall greenhouse gas emissions in the EU in 2019[6], and this share may have increased[7]. Evidence shows that the EU will not be able to reduce net EU greenhouse gas emissions in line with the Climate Law without a

---

[1] European Commission, REPowerEU: Joint European Action for more affordable, secure and sustainable energy, May 2022, COM/2022/108 final.
[2] Council Regulation (EU) 2022/1369 of 5 August 2022 on coordinated demand-reduction measures for gas
[3] European Commission, Proposal for a COUNCIL REGULATION on an emergency intervention to address high energy prices, September 2022, COM/2022/473 final.
[4] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 (the 'European Climate Law').
[5] Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union.
[6] According to the Emission Trading System (ETS) greenhouse gas inventories, 2019.
[7] While the EU's greenhouse gas emissions in the last quarter of 2022 decreased by 6% compared with the pre-pandemic fourth quarter of 2019 and the EU economy is slowly decreasing GHG emissions despite economic growth, the manufacturing, construction and mining and quarrying sectors together remain with the same level of emissions as in 2019. Source: Eurostat (europa.eu).

wide and accelerated scale-up and roll-out of innovative climate-neutral technologies in energy-intensive industries[8].

The **Green Deal Industrial Plan**[9] of 1 February 2023 recognises the need for "modernising and decarbonising energy-intensive industries[10]" and the **Net Zero Industry Act**[11] of 16 March 2023 promotes the manufacturing of innovative net zero technologies to produce, store and transport renewable energy, on which energy-intensive industries will depend, and also supports carbon capture, utilisation and storage (CCUS) technologies. Furthermore, as part of a **revised Industrial Emissions Directive**[12], the Commission has proposed to set up an observatory to identify emerging techniques (INCITE), including those for climate neutral industries, to facilitate their uptake.

To be able to use renewable energy and renewable hydrogen instead of fossil fuels (especially natural gas), energy-intensive industries cannot just buy off-the-shelf technologies. They need **specific technologies for electrification, the integration of hydrogen, carbon capture, utilisation and storage and increased energy efficiency**. Many of the relevant and most effective technologies are still demonstrating how they function in a suitable environment and will need significant private investment and the necessary permits to be able to prove their viability in first-of-a-kind (FOAK) industrial plants to enter the EU market by 2030. Other projects are already at the level of proving their viability in an operational environment in FOAK plants and should be quickly rolled out across energy-intensive sectors in the EU.

This report has been written by the Commission's **inter-service Task Force for Demonstrating Climate Neutral Industries by 2030**[13]**, led by the Directorates-General for Research and Innovation, Climate Action and Internal Market, Industry, Entrepreneurship and SMEs.** It provides an overview of innovation demonstration projects ('demonstrators') for climate neutrality in energy-intensive industries that had received or were receiving funding from EU instruments by the end of January 2023. This overview will help to **capitalise on the major investments that have been made** in demonstrators for decarbonising industries under the EU framework programmes for research and innovation (Horizon 2020 and Horizon Europe), the Innovation Fund and other EU programmes, as well as investments made by Member States in Important Projects of Common European

---

[8] IEA, Net-zero by 2050 (2021); Material Economics, Industrial Transformation 2050 (2019); CapGemini Invent, Fit for Net-zero (2020); European Commission, ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries (2022), see Chapter 2.

[9] European Commission, A Green Deal Industrial Plan for the Net-Zero Age, February 2023, COM(2023) 62 final.

[10] While there is no formal definition of the term 'energy-intensive industries', this report focusses on the sectors proposed by the departments of the Commission in the Commission's Staff Working Document SWD (2021) 277 'For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway'. The energy-intensive industries comprise the chemicals, steel, paper, plastics, mining, extraction and quarrying, refineries, cement, wood, rubber, non-ferrous metals, ferro-alloys, industrial gases, glass and ceramics industries.

[11] European Commission, Proposal for a regulation of the European Parliament and of the Council on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem ('Net Zero Industry Act'), March 2023, COM(2023) 161. The Act constitutes the regulatory pillar of the Green Deal Industrial Plan, together with the Critical Raw Materials Act.

[12] European Commission, Proposal for a DIRECTIVE amending Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) and Council Directive 1999/31/EC on the landfill of waste, April 2022, COM/2022/156 final/3.

[13] Following up on the recommendation in the ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries, which recommended policy action to address the investment gap for low-carbon demonstrators in energy-intensive industries.

Interest (IPCEI). In parallel, international work on clean energy demonstration projects is being pursued under the **Clean Energy Technologies Demonstration Challenge**[14].

The report aims to facilitate a discussion on follow-up financing of demonstrators and, as appropriate and needed, their successful entry into operation and technology transfer across Member States and industries. To this end, it will be key to have the commitment of industry, financing institutions and national authorities, supported by the relevant European partnerships, as well as experienced technology transfer entities such as technology infrastructures, cluster organisations[15], business networks and Enterprise Europe Network (EEN)[16] brokers in the dissemination and exploitation of these results.

1.2. Scope of the overview

The task force has collected information on funded projects and assembled the available data on individual industrial demonstrators[17] *within* projects supported through EU funding instruments, starting with the framework programmes, the Innovation Fund, relevant IPCEIs, InvestEU and the European Regional Development Fund (ERDF). The mapping highlights mature technologies for climate-neutral industries, indicating sectors, location and context of suitable demonstrators which, if considered promising, can be **brought to an industrial scale (first-of-a-kind) demonstration or brought to market by 2030**. The report also creates the basis to pilot technology transfer of specific technologies, which can be replicated in other industries (e.g., steel, cement, chemicals), as pursued through cross-sectoral demonstration projects under the Processes4Planet partnership.

This report presents an overview of **184 demonstrators of technologies for climate neutrality in energy-intensive industries,** which were developed with funding from EU instruments, with a cut-off date of **31 January 2023**. They are at various stages of technological maturity, and most have been supported through Horizon Europe, Horizon 2020, the Innovation Fund and by Member States through IPCEIs.

This interim analysis does not include information on demonstrators that have received national public funding (beyond data available related to IPCEIs), or which were solely funded by the private sector.

As a part of international commitments, such as Mission Innovation[18], Member States including Germany, Austria and Finland have reported on additional demonstrators financed by national resources, which are not part of this overview given the current lack of comprehensive information on them.

[14] Launched by President Biden of the United States and supported by President Von der Leyen: Commission supports the Clean Energy Technologies Demonstration Challenge with over €28 billion by 2027 (europa.eu).
[15] European Cluster Collaboration Platform.
[16] Enterprise Europe Network (europa.eu).
[17] From small-scale industrial demonstrators (TRL 6) to first-of-a-kind commercial demonstrators (TRL 9).
[18] Mission Innovation – Catalysing Clean Energy Solutions for All (mission-innovation.net).

2. OVERVIEW

2.1. Demonstrators for climate neutrality in the EU innovation pipeline

As described above, most of the demonstrators identified by the task force by early 2023 receive funding through the Horizon framework programmes, the Innovation Fund or an IPCEI.

Figure 1 shows the number of industrial demonstrators supported by the different EU instruments. A clear role for each of the instruments in the research and innovation pipeline is apparent: within the framework programmes (Horizon 2020 and Horizon Europe), the key partnerships with industry, such as Processes4Planet and Clean Steel, mostly fund projects aiming for technology readiness levels (TRL) 6 or 7, while the Innovation Fund and IPCEIs aim for TRL 9 (close-to-market, including first-of-a-kind installations) at the end of the respective projects.

Technologies developed in demonstrators at TRL 6-7 need significant follow-up investment to prove their viability in an operational environment and at an industrial scale. When demonstrators obtain this follow-up investment and prove to be viable at TRL 8-9, the focus in terms of public support moves to providing favourable framework conditions to put the technology into operation (permits, grid connection, clusters, skills etc.) and incentives for technology transfer across the EU[19].

Figure 1: Funding programmes in the innovation pipeline
Number of demonstrators funded under each programme, by technology maturity expected upon completion of the project

	TRL 6	TRL 7	TRL 8	TRL 9	Unknown	Total
Horizon 2020	16	66	6	2	3	**93**
Horizon Europe		19	8			**27**
Innovation Fund			4	28	2	**34**
IPCEI	1	1	1	20		**23**
ERDF				1	3	**4**
InnovFin		2				**2**
InvestEU				1		**1**
Total	17	88	19	52	8	**184**

Regarding synergies between programmes, the above data highlight the importance of the Innovation Fund and of IPCEIs for the EU innovation investment pipeline for technologies for climate-neutrality in terms of follow-up to demonstration projects that matured under the Horizon programmes. The overview of projects includes four Innovation Fund projects that had been supported under Horizon framework programmes when they were at a lower technology readiness level[20]. InvestEU's financing conditions would allow the programme to create similar project pipelines between the Horizon framework programmes and the

[19] These factors should be considered in contacts between industry and public authorities as part of the process to decide where to place a first-of-a-kind plant.

[20] Among the projects financed by the Innovation Fund, 14 have a background in the Horizon framework programmes. These projects applied for financing under the usual conditions of calls for proposals under the Innovation Fund. While there is interest in synergies, a project that obtains financing from one EU instrument will not automatically be eligible for funding from another.

InvestEU Green Transition 'window' and between InvestEU windows for Research, Innovation and Development (up to TRL 7-8) and for the Green Transition (incl. TRL 8-9). The programme can contribute to Important Projects of Common European Interest under its 'windows'.[21] However, such a pipeline is currently not apparent[22].

Overall, demonstrators funded by Horizon framework programmes account for more than half of the projects included in the overview, with close to EUR 794 million EU support over a total cost of EUR 1.13 billion for the whole range from TRL 6 to 9. In comparison, the total cost of the smaller number of demonstrators at a higher TRL (8-9) is estimated to be much higher[23] (see the details in Section II.2). This reflects the higher investment needs of demonstrator projects that are at a more mature stage of technological development, which typically have a larger scale.

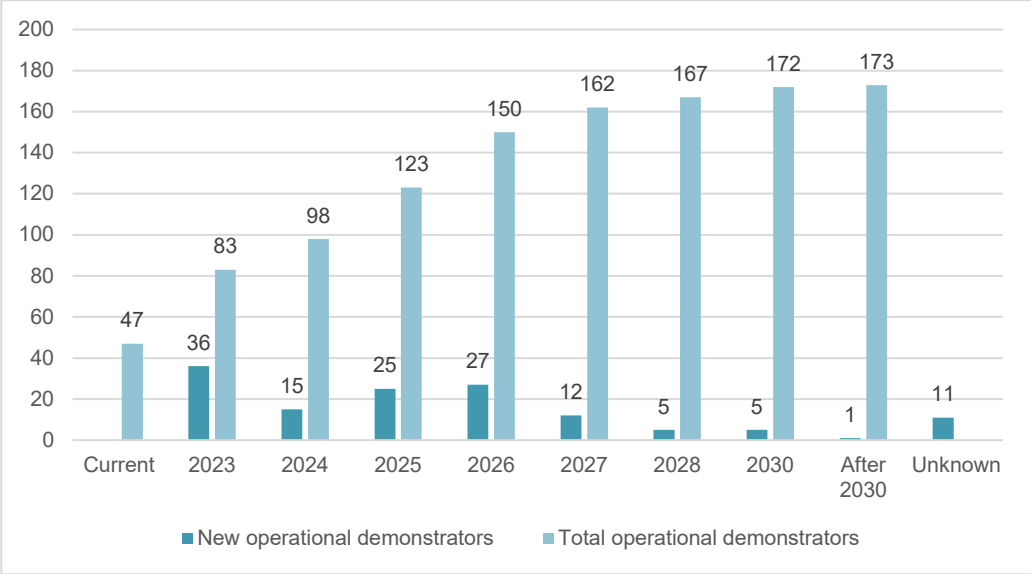
Considering the long investment cycles for energy-intensive industries and the long lead times until demonstrators are fully operational[24], the EU has a strong interest in ensuring that viable projects in the current pipeline are brought to market for a rapid and significant impact on achieving climate neutrality.

Currently, at least 47 demonstrators in this overview have reached their operational phase[25]. The majority are planned or under construction, a few are at the concept or feasibility stage.

Among those that have not yet reached the operational phase within their level of technological readiness, most are expected to reach that status by or before 2027 (at least 127 more projects), and at least 13 more by or before 2030, which will bring the total number of operational demonstrators to at least 173 at the end of 2030[26].

[21] What is the InvestEU Programme? (europa.eu).
[22] Further signed investment projects are still pending for reporting.
[23] These costs are usually not announced by companies because of their commercial sensitivity, the projects being close to competitive and nascent markets.
[24] European Commission, ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries (2022), conclusions, p. 120; IEA, Net-zero by 2050 (2021), p. 124.
[25] For 11 demonstrators in the overview, the status or expected date of entry into operation is unknown. 'Operational' means that a physical installation is built and operated under defined and controlled conditions, and that tests are ongoing.
[26] 'Operational' means that the demonstrator started the operational phase. However, after the demonstrator testing phase finishes many of these prototypes are dismantled or transformed. After the end of a project there is no reporting if they will remain operational over time.

Figure 2: Estimated date of entry into operation and total number of demonstrators that have reached the operational phase over time



2.2. Investment volumes and funding estimates

The EU funding involved in the demonstration projects in this overview currently amounts to **EUR 3.14 billion**.

The projects aiming for a **lower demonstration level** (TRL 6-7), mostly funded under the Horizon framework programmes (in particular, under the partnerships Clean Steel, Processes4Planet and its predecessor SPIRE), but also under IPCEI and InnovFin, had total project costs of **EUR 926 million**, of which EUR 715 million (77%) came from public funding.

From the Innovation Fund (the Energy-intensive industries thematic area), the EU funding for demonstrators included in this overview (mainly reaching **TRL 8-9**) amounts to EUR 2.32 billion, out of the total budget of the demonstrators of **EUR 75.56 billion**[27].

Based on these figures, it is expected that EU funding will leverage ten times more investment in total.

Based on the available information for the IPCEIs, the total budget of the relevant projects in this overview is estimated to be in the range of **EUR 5-10 billion**.

Altogether, current total investments (both private and public) in the demonstration of low-carbon technologies for energy-intensive industries (in the remit of this mapping) amount to an estimated **EUR 85 billion**.

[27] The cost of each individual project cannot be given because of their commercial sensitivity since the projects are close to competitive and nascent markets.

2.3. Technologies for climate neutrality and industrial sectors represented

2.3.1. Technologies demonstrated

The demonstrators in this overview develop low-carbon technologies for energy-intensive industries. The most important groups of technologies, or 'technology pathways' for climate neutrality[28], include green hydrogen integration (41 demonstrators), circularity[29] (41 as well), carbon capture utilisation and storage (CCUS) (36), energy efficiency (35), digitalisation (17) and electrification (14).

Figure 3: Number of demonstrators in each technology pathway

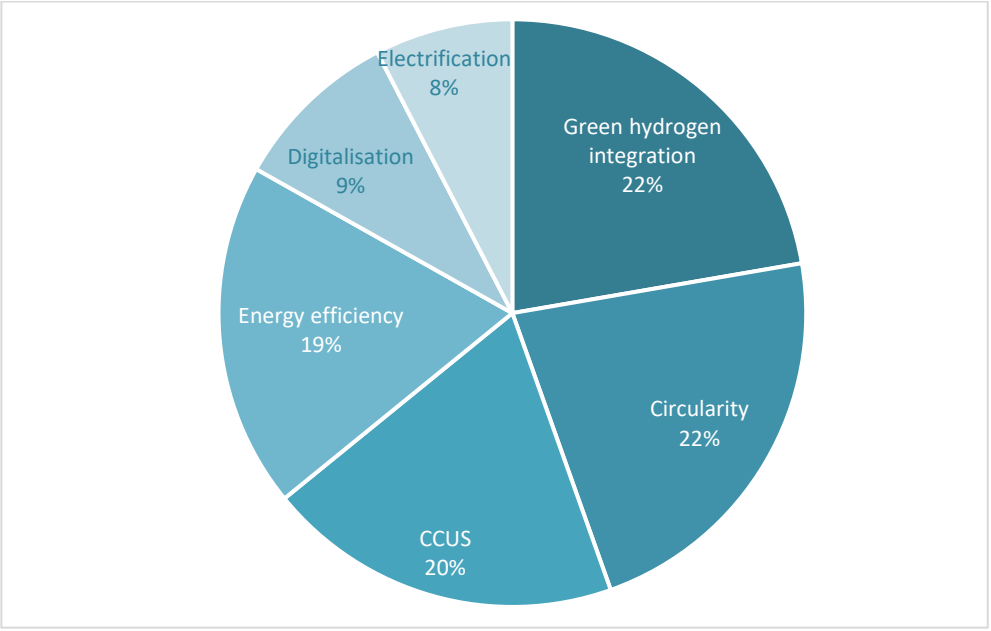


Figure 4 shows that the various pathways or groups of technologies are not at the same level of development and will reach the market at different times. Green hydrogen integration[30] and CCUS technologies are financed by the EU funding instruments and IPCEI, which aim for a TRL that is closer to market, compared to other technological pathways. Overall, energy efficiency, circularity and digitalisation demonstrators are at a lower TRL. However, their technologies seem ready to be deployed as most of these demonstrators aim for TRL 7.

[28] This is in line with the overview of most relevant technological pathways presented in the ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries.

[29] Including alternative resources and industrial symbiosis.

[30] Hydrogen IPCEI launched in 2020 is behind most of the high TRL hydrogen demonstrators in this overview.

Figure 4: Technology pathways in the innovation pipeline
Number of demonstrators in each technology pathway, by technology maturity expected upon completion of the project

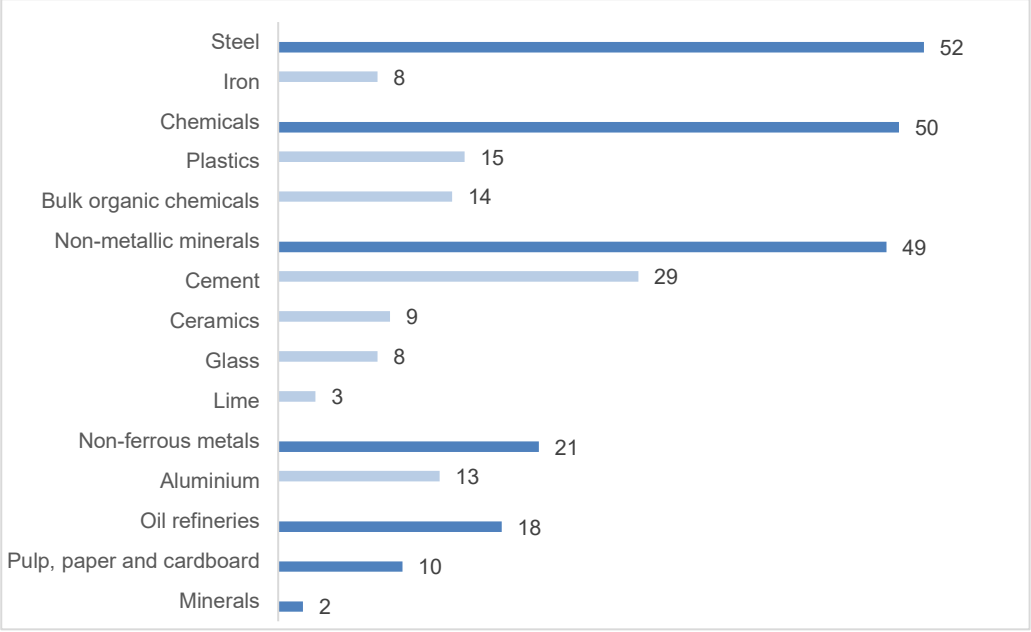
	TRL 6	TRL 7	TRL 8	TRL 9	Unknown	Total
Green hydrogen integration	4	4	6	26	1	**41**
Circularity	1	30	6	3	1	**41**
CCUS	4	12	5	13	2	**36**
Energy efficiency	1	25	2	4	3	**35**
Digitalisation		16			1	**17**
Electrification	7	1		6		**14**
Total	**17**	**88**	**19**	**52**	**8**	**184**

2.3.2. Industrial sectors involved

The industrial sectors covered by the demonstrators in the overview are all energy-intensive industries. Several technologies apply to more than one sector, and some are also being demonstrated to be used in more than one sector[31]. For that reason, figures shown in Figure 5 do not add up to the total number of demonstrators (because some demonstrators are counted more than once, in each relevant sector) but give an indication of how many projects are involved in each sector.

The category 'Multiple' has been assigned to demonstrators that are developing technologies to serve energy-intensive industries, but without specifying a specific sector.

Figure 5: Number of demonstrators in each industrial sector and subsector of energy-intensive industries



[31] In particular energy-intensive industries cross-sectorial innovation is the focus of the Processes4Planet (previously SPIRE) public private partnership.

Overall, the most represented energy-intensive sectors, accounting for more than half of the demonstrators, are steel, chemicals and cement. These three sectors together account for more than 60% of industrial greenhouse gas emissions in the EU[32] and a high share of energy consumption. As stated above, greenhouse gas emissions in the manufacturing, construction and mining and quarrying sectors remain at the same level as in the pre-pandemic period[33]. Since steel, chemicals and cement are the most energy-intensive industries in manufacturing, it can be presumed that also their greenhouse gas emissions have not decreased in recent years.

2.3.3. Focus by technology group

2.3.3.1. Energy efficiency

Technologies to increase energy efficiency include process improvement, heat upgrade from low to high grade, recovery of waste heat energy (including heat pumps), and conversion of waste heat to power. The overview shows that there are a high number of energy efficiency demonstration projects in the steel, non-ferrous metals and cement industries.

The project **CIRMET**, funded under **Horizon 2020**, is developing an energy efficient solution for the **non-ferrous** (**aluminium)** sector and will also assess whether this can be replicated in three other energy-intensive sectors: steel, cement and water. The demonstrator in **Spain** aims for **TRL 7** and is operational. CIRMET's approach to reusing the energy and material waste streams will make it possible to improve process efficiency by 15% while reducing the CO2 emissions of related process by at least 50%.

2.3.3.2. Electrification

Electrification[34] technologies account for 14 demonstrators in the list (8% of the total). They appear mainly in the chemicals sector (six out of 14), followed by the steel sector (four), glass (three) and non-ferrous metals (one). Eight of the demonstrators are at lower TRL (6-7), of which seven are already operational, whereas the six demonstrators at TRL 9 in the overview are either planned to become operational by 2024 or 2025, under construction (ready in 2023) or at the feasibility stage (expected to enter operation in 2027).

The **Horizon 2020** funded project **SIMPLIFY** aims to make it possible to integrate renewable energy by the electrification of chemical processes, in particular in the **speciality chemicals industries**. The three demonstrators in **French** and **Italian** industrial plants are operational at **TRL 6**. The scale-up of the technology developed in this project will represent a 40% energy saving on the targeted processes.

Also funded under **Horizon 2020**, the project **DESTINY** aims to develop efficient electrically driven processes to transform materials in the **cement, steel,** and **ceramic** industries. The demonstrator at **TRL 6** in **Spain** is already operational. The scale-up of the clean technology developed in this project will reduce the CO_2 emissions of targeted steel and ceramic processes by 40% and 90% respectively and provide energy savings of at least 30%.

---

[32] Precisely 63% in total for non-metallic mineral products, basic metals and chemical products (source: ETS and Eurostat data).

[33] Source: Eurostat (europa.eu).

[34] Including electrically driven processes and electrification of thermal processes, except for technologies based on green hydrogen produced through an electrically driven process.

2.3.3.3. Green hydrogen integration

The green hydrogen integration[35] requires specific technologies to integrate hydrogen as a fuel or raw material. Out of the 41[36] demonstrator projects identified, only five appear to be operational at the moment and aim towards TRL 6 or 7. For the demonstrators aiming at TRL 8-9, 22 are planned, 8 are under construction and two are at the feasibility stage. Another 4 demonstrators should become operational in 2023, another 25 by 2030, and one afterwards. 12 demonstrators develop technologies to integrate hydrogen as a raw material and 39 as a fuel.

The demonstrator **H2CEM** (funded under the **Hy2Use IPCEI**) aims at the production, storage and green hydrogen integration to produce energy in furnaces, resulting in the decarbonisation of **cement** plants. The demonstrator is located in a **Greek** industrial plant.

In 2016, SSAB, LKAB and Vattenfall joined forces to create the **HYBRIT** demonstrator and received EU support under the **Innovation Fund**. HYBRIT aims to replace coking coal, traditionally needed for ore-based **steel** making, with hydrogen. The result will be the world's first fossil-free steel-making technology, with virtually no carbon footprint. The demonstrator, located in the **Swedish** town of Luleå, will be operational by **2027** and should be ready to move from demonstration to deployment by around 2035.

2.3.3.4. CCUS

After hydrogen integration, CCUS is the most represented technology pathway with a high TRL in this overview (18 demonstrators at TRL 8-9), which means that the technologies in this pathway are closer to market. However, only five of the 43 demonstrators identified in this overview are already operational, and they are at TRL 6, 7 or 8. The 13 demonstrators aiming for TRL 9 are scheduled to become operational between 2024 and 2028.

The Belgium-based demonstrator **Steelanol** (funded under **Horizon 2020** and **InnovFin**) was launched in December 2022. The demonstrator recycles carbon-rich gases in the steel industry and transforms them into advanced sustainable ethanol to reduce carbon emissions. A similar objective is pursued by the Horizon 2020 **C4U** project that intends to build **TRL 7** demonstrator plants in Sweden and Spain. The scale-up of the advanced clean technology developed by C4U could result in a 90% reduction in CO_2 emissions from steel production and a potential reduction of up to 50% of the primary energy consumption of the CCU process.

2.3.3.5. Circularity

This category comprises the circular use of resources, via recycling and upcycling, within the same value chain or sector and across different sectors (industrial symbiosis). The systemic shift - with industries moving towards full circularity - hinges on greater cross-sectoral collaboration and interaction with neighbouring cities and regions. This is the purpose of Hubs4Circularity[37] (sites or valleys), which aims to speed up regional collaboration in industry and wider society to develop technologically innovative local-level solutions and ensure widespread public involvement. At EU level, the first Hubs4Circularity demonstrators will be supported under Horizon Europe's Cluster 4 'Digital, Industry and Space' (Work Programme 2023-24). The recently published Critical Raw Materials

[35] Including hydrogen integration as energy (fuel) and using hydrogen as a raw material/chemical biogenic feedstock.
[36] This figure is significant because of the Hydrogen IPCEIs that are within the scope of this mapping, which also explains the higher TRL range.
[37] European Commission, Hubs for circularity – Keeping local with a global impact (2022).

Communication[38] proposes to mobilise up to EUR 200 million to create 10 additional Hubs for Circularity.

The high number of circularity-related projects (41, of which 31 on the circularity of materials through recycling or upcycling) is striking and shows the important role that circularity plays for achieving climate neutrality.

The **Horizon 2020** project **CORALIS** will demonstrate the efficiency of industrial symbiosis in three industrial parks, constituting an embryo of Hubs4Circularity:

- In Escombreras (**Spain**): a novel process will be set up to produce potassium nitrate (KNO_3) that enables the use of by-products (sulfuric acid/H_2SO_4), residues (Ca contained in wastewater) and the CO_2 emissions of the industrial area.
- In Höganäs (**Sweden**): an integrated unit for CO_2 capture and recovery of waste heat from the Höganäs **steel** company will be installed to supply a greenhouse. The scheme will also work with a fish farm on the exchange of waste heat and organic waste as fertilisers and will work on the revalorisation of slag for civil construction works and other applications.
- In Brescia (**Italy**): four industries will work together in a collaborative scheme for the exchange and revalorisation of industrial waste. The objective is to use metal powder, metal oxides and other industrial wastes to produce **steel, iron** and **aluminium**, as well as to substitute coal with biogenic materials. An analysis will be carried out on including slag in this scheme and making use of recovered heat in district heating.

The results will improve the energy efficiency of the targeted industrial processes by at least 15%, (compared to the non-symbiotic scenario), reduce the total energy intensity by at least 30%, based on the full industrial life cycle, and will lead to **an overall reduction in CO_2 emissions of 40%** (idem). In addition, a reduction in primary raw material intensity of up to 20% and in waste generation of at least 25% will be achieved.

2.3.3.6. Digitalisation

Digitalisation and the integration of IT systems account for some demonstrators in the list, mostly at TRL 7, often embedded in the other technology pathway demonstrators. e.g., energy efficiency and renewable energy integration (mainly electrification)

2.4. Location of demonstrators in EU Member States and other ERA countries

The country with the most demonstrators in the overview is Spain with 33 demonstrators, followed by Italy and Germany (21 each), France (14), the Netherlands and Belgium (11 each), Sweden and Austria (10 each). The other countries each have fewer than ten demonstrators on their territory. Central and eastern Europe have fourteen demonstrators in total, with most in Czechia (four), followed by Poland and Slovenia (three each).

In total, 18 EU Member States host at least one demonstrator. Another 12 demonstrators are located outside the EU, of which half in Norway. Overall, there is a reasonable geographical spread of the demonstrators in this mapping, albeit with a clear gravitation towards certain countries.

A slightly different picture emerges if we look specifically at the funding programme involved and therefore the technological maturity of the projects. Sweden is involved in a bigger proportion of more mature projects and Germany in less mature ones.

[38] European Commission, Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability, September 2020, COM/2020/474 final.

For a detailed description of the situation in each country, see Section III of this report.

Figure 6: Total number of demonstrators by location

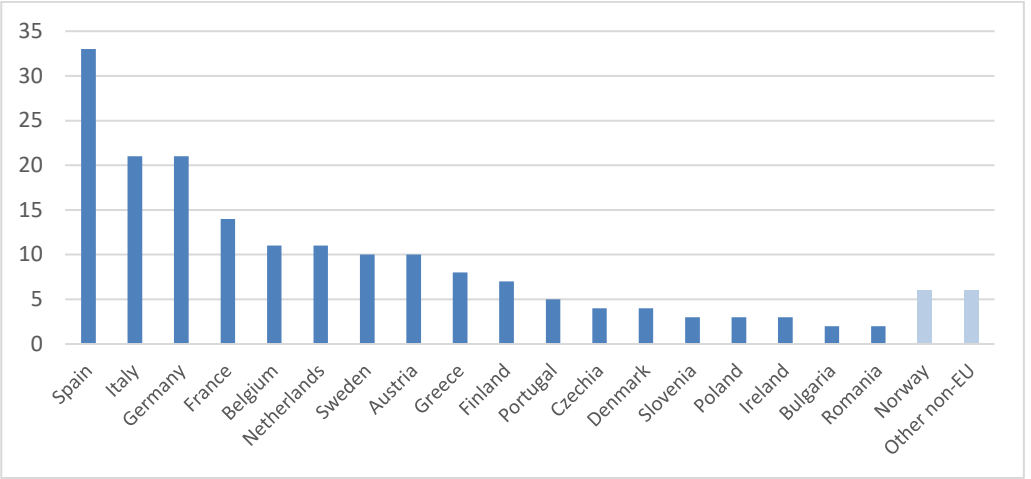
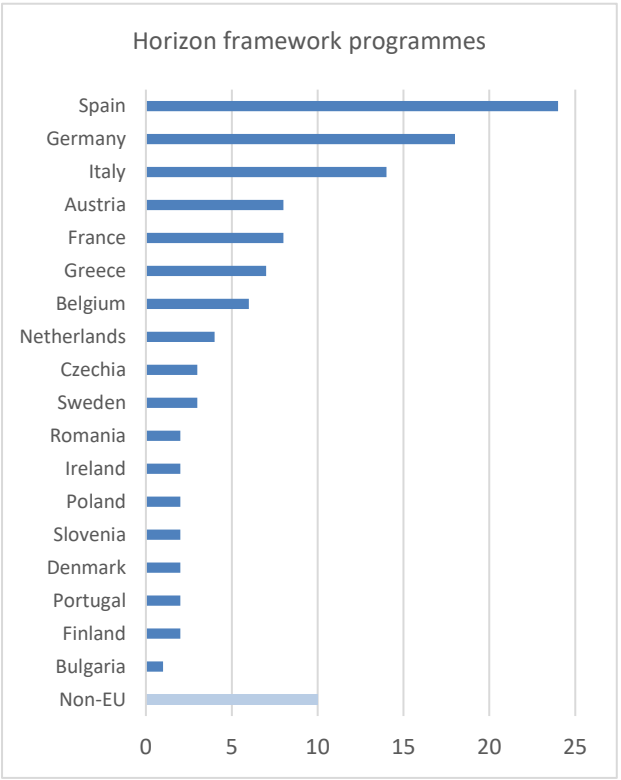
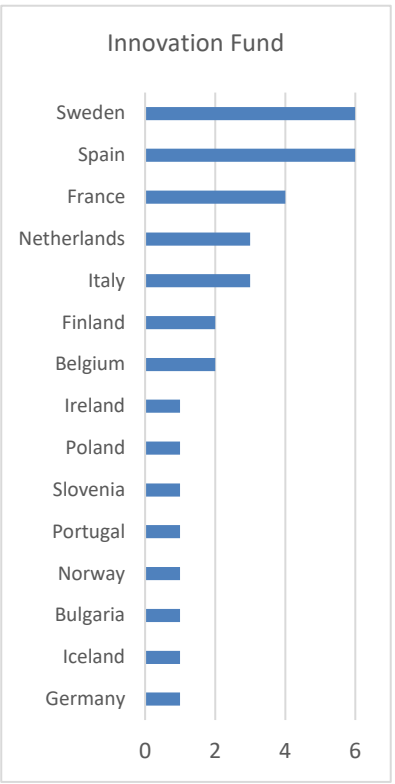


Figure 7: Number of demonstrators by location and funding programme





2.5. Gap analysis

This section presents findings on the weights of specific technological solutions developed in different energy-intensive sectors, based on the thematic analyses above. As above, this only concerns demonstrators developed with funding under EU instruments or in cross-border cooperation projects.

Figure 8 focuses on the link between technology groups and sectors. As for Figure 5, a demonstrator that is working in more than one sector is counted in the relevant technology group for each of the sectors.

Figure 8: Industry representation by technology group

	Green hydrogen integration	Circularity	CCUS	Energy efficiency	Digitalisation	Electrification
Steel	12	11	6	9	10	4
Chemicals	11	20	7	3	3	6
Cement	2	3	14	8	2	
Aluminium	1	5		4	2	1
Other non-ferrous metals		2		3	3	
Oil refineries	9	1	5	3		
Multiple	3	2	6			
Pulp, paper and cardboard	3		2	5		
Glass	1		1	2	1	3
Ceramics	1		1	5		2
Other minerals			1	1		

Based on this overview, some observations can be made:

- Energy efficiency technologies are represented in **all industries**.[39]
- The non-metallic minerals sector (**cement, ceramics** and **glass** industries) puts much emphasis on CCUS and on energy efficiency technologies[40]. On the contrary, few green hydrogen integration and circularity technologies are among the demonstration projects mapped in this sector. Electrification[41] technologies projects can be found in the glass and ceramics industries but not in the cement industry.
- Circularity technologies are well represented in the **chemicals** industry.

[39] Energy efficiency and circularity were the focus of Horizon 2020 SPIRE projects. This partially explains the large number of demonstrators in these technology groups.

[40] A particularity of the cement industry is that almost 60% of their CO_2 emissions are not linked to the use of energy but are process emissions, which result from chemical reactions and therefore cannot be avoided by switching to alternative fuels (hydrogen or electricity).

[41] Due to the cement industry's limited access to grid power, the use of hydrogen is considered a more attractive option to integrate renewables than electrification. However, access to grid is not always a (strong) limitation for electrification, as cement producers are investing in local renewable energy sources. For more details, see Marmier, A., Decarbonisation options for the cement industry (2023).

- The **pulp, paper and cardboard** industry does not have any demonstrators for circularity or electrification technologies[42].
- There is no demonstrator for CCUS in the non-ferrous metals sector (i.e., including the **aluminium** industry) and only one for hydrogen integration[43] (at the time of preparing the information in Figure 8[44]).

As regards the location of demonstrators, Slovakia and Hungary, despite the role of energy-intensive industries in their economies, do not have any demonstrators for low-carbon energy-intensive industries, funded by an EU instrument, on their territories.

[42] The pulp, paper and cardboard industry was not formally an energy-intensive sector under the Horizon 2020 SPIRE partnership. This industry is part of the Circular Bioeconomy Europe Joint Undertaking, and circularity for added value bio-based products is addressed there. Those demonstrators are not included here. Pulp and paper processes use very low temperatures, so they face fewer challenges with respect to the electrification of processes. Electrification of other relevant processes e.g., bleaching is covered by R&I agendas.

[43] In the report Eurometaux, Metals For a Climate Neutral Europe: a 2050 Blueprint (2019), these two technologies are also not really identified as viable options in that sector, except in cases where there are direct synergies or links with iron and steel production.

[44] Two demonstrators on hydrogen integration in the aluminium sector, HyInHeat and H2GLASS, started in 2023 under the 2022 work programme of Horizon Europe.

3. COUNTRY SPECIFICITIES IN MEMBER STATES AND OTHER ERA COUNTRIES WITH RELEVANT DEMONSTRATORS

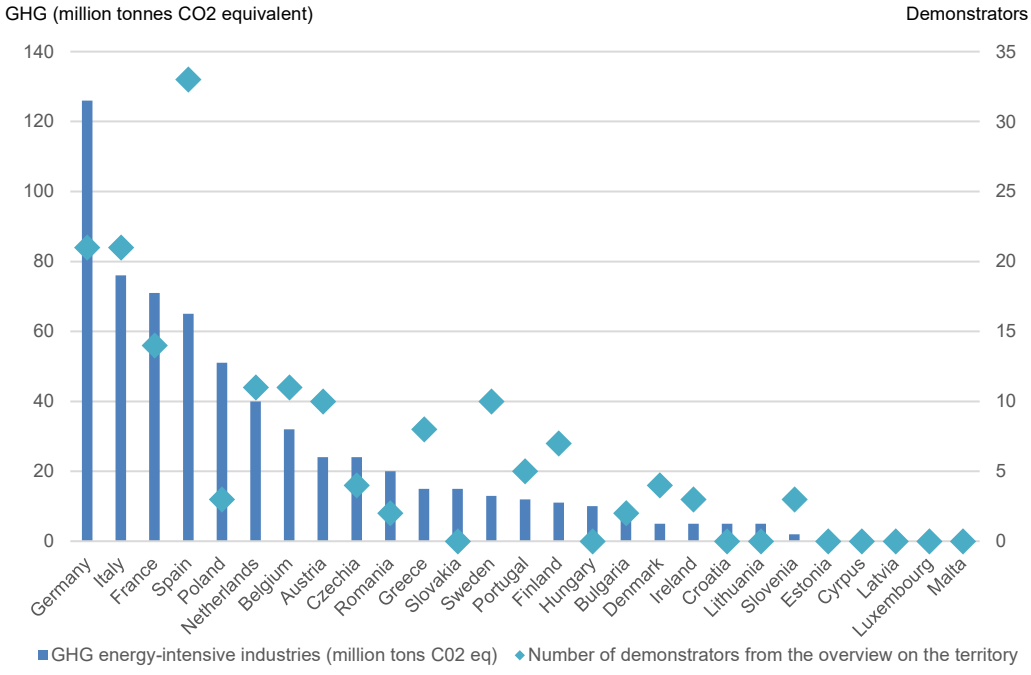
This chapter presents overviews for each country in the European Research Area (ERA) that has at least one demonstrator on their territory that is within the scope of this mapping, and which received funding under EU instruments. To create this mapping, the Commission examined the list of projects funded under EU programmes (the Horizon framework programmes, the Innovation Fund, cohesion funds) and Important Projects of Common European Interest (IPCEIs).

This document provides facts and figures about existing innovation demonstration projects, which have been or are currently supported by EU instruments. It does not endorse any of the projects mentioned or recommend follow-up support. No assessment of the projects contained in this document has been made, other than to indicate that they have been selected for financial support under the relevant instrument.

In each of the country sections below, the list of demonstrators located in the country is provided, either in the section itself or, if the country has more than ten demonstrators, in the Annex at the end of the document.

Figure 9 shows the estimated greenhouse gas emissions attributed to energy-intensive industries in each EU Member State, which is interesting to compare with the number, size and technological maturity of the demonstrators located there.

Figure 9: greenhouse gas emissions attributed to energy-intensive industries in EU Member States



Source: European Environment Agency, GHG Data Viewer.

3.1. Belgium

Relevant demonstration projects, description and funding

Belgium hosts **11 demonstrators for low-carbon technologies in energy-intensive industries,** which receive funding from EU instruments. The full list is available in the annex.

Eight of these demonstrators are funded under **Horizon** framework programmes, of which two also receive funding from **InnovFin**, and two others are part of multi-country projects, namely **CAESAR** and **ReActiv.** These eight projects at **TRL 6-8** that are located at least partially in Belgium demonstrate technologies in the fields of **CCUS, hydrogen integration** and **circularity.**

Three of these demonstrators are **operational** (at TRL 7). Two are **under construction** and will reach their target TRL (6 and 7) in **2023 and 2024**. Two demonstrators aiming at TRL 8 are still at the **feasibility** stage, and another one is **planned** to reach this TRL in **2030.** Private follow-up investment will be decisive if the demonstrated technologies are to be brought to market.

The projects **CO2ncrEAT** and **Kairos@C** receive support under the **Innovation Fund**, amounting to EUR 4.5 million and EUR 357 million, respectively. They both demonstrate **CCUS** technologies and are **planned to get close to market in 2025**, in the **cement** industry in Liège and in the **chemicals** sector in Antwerp, respectively.

The **ENGIE** project listed under the **Hydrogen IPCEI** plans to demonstrate a **hydrogen** integration technology, which will be **close to market by 2030,** in a **steel** plant in Charleroi.

These three projects that are **close to market** are planned to become operational between 2025 and 2030. They will demonstrate technologies in **CCUS** and **green hydrogen integration**.

Overall, the sectors covered by the demonstration projects in Belgium are most **energy-intensive industries**: steel, cement, chemicals, oil refineries and non-ferrous metals. There appears to be no demonstrator, in the scope of this mapping, for **electrification** and **energy efficiency** technologies in Belgium.

Belgium's energy-intensive industries emit around 32 million tonnes of CO_2-equivalent in greenhouse gases annually.

Conclusions

Belgium could verify with industry which of the technologies already demonstrated at (or reaching) TRL 6-8 should be brought to the level of a first-of-a-kind plant (TRL 9).

The existing multi-country cooperation in the **ReActiv** project creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The three projects aiming to get close to market could have proven their viability by 2025. They would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.2. Bulgaria

Relevant demonstration projects, description and funding

Bulgaria has **two demonstrators** for low-carbon technologies in energy-intensive industries, which receive funding under an EU instrument.

- **ANRAV-CCUS** (pioneering CCUS in Bulgaria): this **CCUS** project has been granted EUR 190 million in support from the **Innovation Fund**. The demonstrator located in the Heidelberg **Cement** plant in Varna aims to be **close to market by 2028**, and to save 7.8 million tonnes of CO_2 equivalent in greenhouse gases during its first ten years of operation.

- **FLEXIndustries** (Digitally enabled FLEXible Industries for reliable energy grids under high penetration of Variable Renewable Energy Sources): this **Horizon Europe** project has received EUR 12 million to demonstrate an **energy efficiency** technology at **TRL 7** by 2026, in three locations. The demonstrator located in Bulgaria will operate in the STOMANA plant in Pernik, in the **steel** sector, with a planned emissions reduction of 33,000 tonnes of CO_2-equivalent in greenhouse gases per year. Two other demonstrators in Germany and Greece are planned in the **pulp and paper** and **cement** industries, respectively.

Currently, Bulgaria does not have any demonstration project, in the remits of this mapping, to develop **hydrogen integration** and **electrification** in energy-intensive industries; nor in the **chemicals** sector, which is among the most emitting industries.

The **FLEXindustries** demonstrator described above aims to reach TRL 7. Private follow-up investment will be decisive if technologies are to be brought to market.

Bulgaria's energy-intensive industries emit around 8 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Concerning the **FLEXindustries** demonstrator, Bulgaria could consider engaging with industry to verify whether it should be brought to first-of-a-kind level (TRL 9) in the coming years. The existing multi-country cooperation in this project creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The project **ANRAV-CCUS**, which is already close to market, would benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.3. Czechia

Relevant demonstration projects, description and funding

Czechia has **four demonstrators** for low-carbon technologies in energy-intensive industries that receive funding under an EU instrument.

- **CO2OLHEAT** (Industrial waste heat valorisation for energy-intensive industries): at the concept stage, this **Horizon 2020** project plans to demonstrate a technology to produce power from waste heat in CEMEX's Prachovice **cement** plant at **TRL 7** by **2025.** The project plans to save 40 GWh of primary energy and 6,500 tonnes of CO_2 per year.

- **DECAGONE** (Demonstrator of industrial carbon-free power generation from ORC-based waste-heat-to-Energy systems): funded under **Horizon Europe**, it is planned to demonstrate a waste heat to power technology in the **steel** sector at **TRL 7** in **2026**. The demonstrator is located in Třinec and aims to save 4,500 tonnes of CO_2 per year and reduce primary energy consumption by 26 GWh per year (reducing the energy footprint by 4%).

- **Reduction of energy performance (technological process) of steel heat treatment in forge production:** this project has received EUR 788,240 under the **ERDF** to demonstrate a waste heat energy recover technology in the **steel** sector in the Hradec Králové region. It is already **operational** and aims to reduce energy consumption in heat treatment of steel by 36.5%.

- **SPIRIT** (implementation of sustainable heat upgrade technologies for industry): this **Horizon Europe** project is demonstrating energy recovery from waste heat in the **pulp and paper** industry and aims to reach **TRL 8** in **2026**.

All projects are between TRL 7 and 8. Private follow-up investment will be decisive if technologies are to be brought to market.

All projects demonstrate **energy efficiency** technologies. The energy-intensive sectors covered are steel and cement. It was not possible to identify demonstrators for other technological pathways or other energy-intensive sectors within the scope of this exercise.

Czechia's energy-intensive industries emit around 24 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Czechia could verify with industry which of the technologies already demonstrated at TRL 7 or 8 by 2025 or 2026 should be brought to the level of a first-of-a-kind plant (TRL 9). As all these demonstrators are multi-country projects, the possibility of obtaining follow-up investment could be explored with partner countries.

3.4. Denmark

Relevant demonstration projects, description and funding

Denmark has **four demonstrators** for low-carbon technologies in energy-intensive industries that receive funding under EU instruments.

- **MEGASYN:** this multi-country project demonstrates an energy efficiency technology in the steel and chemicals sectors. It received EUR 5 million from **Horizon 2020** and is coordinated by Danmarks Tekniske Universitet. The project will lift the technology from TRL 5 to **TRL 7** by **2025**.

- **GreenCem:** this project investigates the possibilities for **storage and utilisation of the** CO_2 that will be captured from Aalborg Portland's **cement** production processes. It will be operational at **TRL 8** and has been granted **DKK 6.76 million** (EUR 907,192).

- **HySynergy:** under a Hydrogen IPCEI, this demonstrator led by Everfuel establishes a 20 MW Power-to-X (PtX) facility in Fredericia. It will offer **green hydrogen** to

transportation and industrial partners and is expected to be operational at **TRL 9** by **2025**.

- **ConsenCUS** (Carbon-neutral clusters through electricity-based innovations in capture, utilisation and storage): this multi-country project has been granted around **EUR 12.9 million** from **Horizon 2020** and demonstrates **carbon capture** technologies also in Greece and Romania. In Denmark, Aalborg Portland demonstrates this technology for the cement industry at TRL 8.

The **Horizon** projects will demonstrate technologies at TRL 7-8 before 2025. Private follow-up investment will be decisive if technologies are to be brought to market.

The projects located in Denmark are developing technologies around carbon capture, energy efficiency and renewable hydrogen integration. They cover the cement, steel, chemicals, and oil refineries sectors.

Denmark's energy-intensive industries emit around 5 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Denmark could verify with industry which of the technologies reaching TRL 7 or 8 by 2025 or 2026 should be brought to the level of a first-of-a-kind plant (TRL 9). For the demonstrators in multi-country projects, the possibility of obtaining follow-up investment could be explored with partner countries.

The demonstrator **HySynergy,** aiming to get close to the market, could have proven its viability by 2025. It would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.5. Germany

Relevant demonstration projects, description and funding

Germany has **22 demonstrators** for low-carbon technologies in energy-intensive industries that receive funding under an EU instrument. The full list is available in the annex.

Seventeen of these demonstrators are funded under **Horizon** framework programmes, for a total cost of EUR 134 million, and an EU contribution of EUR 96 million (roughly, by applying a pro rata on the Horizon projects set in different locations). Five of these demonstrators are part of multi-country projects.

The **Carbon2Business** project (**C2B**) is the only demonstrator in Germany developing low-carbon technologies that is supported by the **Innovation Fund.** The total cost of the project is EUR 6 billion and the EU contribution is EUR 110 million (less than 2% public funding leverage). It is developing a carbon capture technology that will get **close to market in 2028**.

Three demonstrators are part of projects with links to a **Hydrogen IPCEI**. They will all demonstrate hydrogen integration technologies.

Most of the Horizon projects will demonstrate technologies at TRL 7, two at TRL 6 and two more at TRL 8, all before 2026.

The project **GrinHy 2.0** demonstrates a technology around the green hydrogen integration and was already close to market by 2023.

The demonstrators at TRL 6 to 8 develop technologies around **energy efficiency**, the green hydrogen integration, **carbon capture and storage**, **electrification**, **circularity** and **resource efficiency**.

The sectors covered by the demonstration projects in Germany are in the most energy-intensive industries: steel and iron, cement and lime, chemicals including plastics, non-ferrous metals, oil refineries and pulp, paper and cardboard.

Germany's energy-intensive industries emit around 126 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Germany could verify with industry which of the 16 demonstrators at TRL 6 to 8 funded under **Horizon** framework programmes should be brought to the level of a first-of-a-kind plant (TRL 9).

The existing multi-country cooperation in relevant Horizon framework programme projects (**FLEXIndustries, intelWATT, LEILAC-2, REVaMP** and **PUSH2HEAT**) creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to the market.

The demonstrators **C2B** and **Grinhy,** demonstrating close to market technologies, could have proven their viability by 2025. They would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.6. Ireland

Relevant demonstration projects, description and funding

Ireland has **three demonstrators** for low-carbon technologies in energy-intensive industries that receive funding under EU instruments.

- **AAL SEB**: this project aims to partially decarbonise the production of high-pressure steam used in an **aluminium** refinery, by substituting existing gas-fired boilers with an **electric** boiler that is powered during peak renewable production. It has received around **EUR 4.2 million** from the **Innovation Fund** and will begin operating in its close-to-market phase in **Q3 2023**.

- **COGNIPLANT**: this multi-country project will supply industrial plants with a supervisory **control solution** for its production process and its energy and resource needs. It has received around **EUR 6.7 million** of funding from **Horizon 2020**. It will be operational **in 2023 at TRL 7** and has the potential to reduce greenhouse gas emissions by 18%.

- **REALISE:** this multi-country project is demonstrating a **CCUS** technology in an **oil refinery** in Cork. It has received around **EUR 6.4 million** in funding from **Horizon 2020** and is being developed to reach **TRL 6.**

The two Horizon 2020 projects will demonstrate technologies at TRL 6 and 7 and develop technologies around energy and resource efficiency, and carbon capture and storage.

The sectors involved in the demonstration projects in Ireland are steel, aluminium and oil refineries.

Ireland's energy-intensive industries emit around 5 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Ireland could verify with industry which of the demonstrators reaching **TRL 6 and 7 before 2026** and funded under **the Horizon** framework programmes should be brought to first-of-a-kind level (TRL 9).

The **Innovation Fund** project **AAL SEB**, which plans to demonstrate technologies close to market before 2025, could have proven its viability by then. It would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.7. Greece

Relevant demonstration projects, description and funding

Greece has **eight demonstrators** for low-carbon technologies in energy-intensive industries that receive funding under EU instruments.

- **BAMBOO**: this multi-country project is developing new approaches to flexibility management by optimising off-gas and waste use processes to increase **energy efficiency** in the **minerals** industry. Grecian Magnesite and CERTH from Greece are participating. The project has received around **EUR 10.4 million** from **Horizon 2020** and the results are **already operational** at **TRL 7**.

- **IntelWATT**: this multi-country project, with **Horizon 2020** funding of around **EUR 10.3 million**, is developing innovative separation technologies in energy- and water-intensive industries to demonstrate **resource efficiency** and **circularity**. The demonstrator in Greece is planned to reach **TRL 8** in **2024.**

- **ENSUREAL:** this multi-country project consisted of an integrated cross-sectorial approach for environmentally sustainable and **resource-efficient alumina** production. The company Mytilineos participated from Greece. The project received around **EUR 7.3 million** from **Horizon 2020** and the results are **already operational at TRL 7**.

- **ReActiv**: this multi-country project is creating a novel and sustainable **symbiotic** value chain, linking the by-products of **alumina** and **cement** production industries. The company Mytilineos is involved from Greece. The project received around **EUR 8.8 million** from **Horizon 2020** and is **already operational at TRL 7**.

- **ConsenCUS** (Carbon-neutral clusters through electricity-based innovations in capture, utilisation and storage): this multi-country project, which has received around **EUR 12.9 million** in funding from **Horizon 2020**, demonstrates **carbon capture** technologies, including at Grecian Magnesite, and is planned to reach **TRL 7** by **2025**.

- **FLEXIndustries**: this multi-country project, with around **EUR 12.4 million** in funding from **Horizon Europe**, promotes the most suitable **energy efficiency** measures and process flexibility methods for **energy intensive industries**. The **cement** company Titan, from Greece, is taking part in the project, which is expected to begin operation at **TRL 7** by **2026**.

- **TRINEFLEX**: this multi-country project aims to manage the **digital** lifecycle of **energy-intensive plants** and the transition towards flexible and sustainable operations. In Greece, the copper (**non-ferrous metals**) company Halcor was involved. The project will receive around **EUR 16.3 million** from **Horizon Europe** and will be reach **TRL 7** by **2026.**

- **H2CEM:** this project is developing the production of **green hydrogen** through electrolysis at Titan **cement** plants in Greece (Kamari in Boeotia, Drepano in Achaia and Efkarpia in Thessaloniki). It aims to be **close to market in the coming years** and will lead to a reduction in CO_2 emissions of 160,000 tonnes per year. The total cost of the project is **EUR 60 million** and it will receive State aid under the **Hy2use IPCEI**.

Most of the **Horizon** projects have or will demonstrate technologies at TRL 7 and 8, all before 2026. These projects need private investment to bring technologies they demonstrate to market.

The demonstrators at TRL 6 to 8 are developing technologies around **energy efficiency**, **carbon capture and storage**, **circularity** and **resource efficiency**. There is no electrification demonstration project to our knowledge. The H2CEM project is demonstrating a technology around the green hydrogen integration at TRL 9.

The sectors covered by the demonstration projects in Greece are **cement** (and other minerals), **steel** and non-ferrous metals (**aluminium** and **copper**).

There are currently no Innovation Fund projects.

Greece's energy-intensive industries emit around 15 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Greece could verify with industry which of the technologies demonstrated at TRL 7-8, and funded under **Horizon** framework programmes, could be brought to the level of first-of-a-kind plants (TRL 9). Existing multi-country cooperation in these projects creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The **H2CEM** demonstrator is demonstrating technologies that are close to market and could prove its viability in the coming years. The project could then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.8. Spain

Relevant demonstration projects, description and funding

Spain has **33 demonstrators for low-carbon technologies in energy-intensive industries** that receive funding under an EU instrument. The Commission has identified it as the country with the highest number of demonstrators financed at EU-level. The full list is available in the annex.

A total of 23 of these demonstrators are funded under the **Horizon** framework programmes. These projects have a total cost of EUR 123 million and receive total EU funding of **EUR 98 million**[45]. They demonstrate technologies for climate-neutrality at **TRL 6,7 and 8** in the areas of: **circularity** and **resource efficiency** (11 demonstrators), **digitalisation** (6), **energy efficiency** (5), **hydrogen integration** (1). Private follow-up investment will be decisive if technologies are to be brought to market.

Six demonstrators have received support under the **Innovation Fund** for a total of **EUR 120.2 million** to demonstrate technologies close to market by or before 2025. Three of them demonstrate technologies on the **integration of renewable hydrogen**; the other three are in the areas of: **energy efficiency**, **carbon capture and utilisation**, and **circularity**.

Four demonstrators are part of projects listed under the **Hydrogen IPCEI**[46]. They all demonstrate **hydrogen integration** technologies at **TRL 9** by or before 2027.

There appears to be no demonstrator in Spain for **electrification** technologies.

The sectors covered by the demonstration projects in Spain include most of the energy-intensive industry sectors: **steel**, non-ferrous metals including **aluminium**, non-metallic minerals including **cement**, **lime**, **ceramics** and **glass**, **chemicals** including plastics and fertilisers, and **oil refineries**. The iron and pulp and paper industries are missing.

A total of 19 demonstrators are already or will be operational by the end of 2023, four more will reach the operational phase for their target TRL each year until 2026, then two in 2027.

Spain's energy-intensive industries emit around 65 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Spain could verify with industry which of the technologies already demonstrated at (or reaching) TRL 6-8 before 2025 should be brought to the level of a first-of-a-kind plant (TRL 9).

The existing multi-country cooperation in the 16 projects funded by Horizon 2020 creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

[45] Roughly, by applying a pro rata on the cross-country projects counting many demonstrators - 16 of these demonstrators are part of cross-country projects.
[46] Hy2Use; complementary to the Hy2Tech for mobility applications.

The ten projects that are already closer to market could have proven their viability by 2025. They would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.9. France

Relevant demonstration projects, description and funding

France has **14 projects** demonstrating technologies for climate-neutrality in energy-intensive industries, and which receive funding under EU instruments. The full list is available in the annex.

Eight of these demonstrators are funded under **Horizon** framework programmes, for a total cost of EUR 58 million, and an EU contribution of EUR 48 million. Three of these demonstrators are part of multi-country projects.

A demonstrator located in Auvergne under the project **WHIN** (Waste heat recovery in the silicon industry) received EUR 6 million co-financing from the **European Regional Development Fund** and the **LIFE** programme. Its total cost is EUR 13 million. It demonstrates a technology in waste heat energy recovery (**energy efficiency**) in the **chemicals** sector and is already operational at TRL 7-8.

Four projects have received EUR 285 million in total under the **Innovation Fund** to demonstrate technologies already close to market.

The **MassHylia** project listed under the **Hydrogen IPCEI**, will demonstrate a close-to-market hydrogen integration technology by 2026 in oil refineries in Marseille.

The ten projects at **TRL 6-8,** located at least partially in France, demonstrate technologies in the fields of **electrification, CCUS, digitalisation, energy efficiency** and **circularity.** Private follow-up investment will be decisive if technologies are to be brought to market.

Six of these demonstrators are already **operational**, one will be operational in 2023, two will reach their target TRL in 2026 and one in 2027.

The more mature projects will demonstrate technologies in **energy efficiency, electrification, CCUS and the green hydrogen integration** by or before 2028.

The sectors covered by the demonstration projects in France include most sectors of the **energy-intensive industries**: glass, steel, cement, chemicals, oil refineries and non-ferrous metals.

France's energy-intensive industries emit around 71 million tonnes of CO_2-equivalen in greenhouse gases per year.

Conclusions

France could verify with industry which of the technologies demonstrated already at (or reaching) TRL 6-8 before 2025 should be brought to the level of a first-of-a-kind plant (TRL 9).

The existing cross-country cooperation in relevant projects funded by the Horizon programmes (**CAESAR, SIMPLIFY** and **TRINEFLEX)** creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The four projects that are already closer to market could have proven their viability by 2025. They would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.10. Italy

Relevant demonstration projects, description and funding

Italy has 21 demonstrators for low-carbon technologies in energy-intensive industries that receive funding under EU instruments. The full list is available in the annex.

Fourteen of these demonstrators are funded by the **Horizon** framework programmes, with a total cost of EUR 113.9 million, and an EU contribution of around **EUR 87.5 million**[47]. Eight of these demonstrators are part of multi-country projects.

The 14 projects are demonstrating technologies in the areas of: **energy efficiency** (6 projects), **circularity and resource efficiency** (4), **digitalisation** (1), **electrification** (1), **carbon capture** (1) and **hydrogen integration** (1).

Three demonstrators have received **13 million** in funding from the **Innovation Fund**. They plan to demonstrate technologies close to market by or before 2025 in the areas of hydrogen integration, energy efficiency and electrification.

Four demonstrators are part of projects listed under the **Hydrogen IPCEI**[48]. They will all demonstrate hydrogen integration technologies close to market after 2027.

Most of the projects funded by the Horizon framework programmes will demonstrate technologies **at TRL 7**, one **at TRL 6** and two **at TRL 8**. Nine of them are or will be **operational by or before 2026**, two more by 2027, and the last one by 2030. Private follow-up investment will be decisive if the technologies developed by these projects are to be brought to the market.

The sectors covered by the demonstration projects in Italy include **all the energy-intensive industries**: steel, cement, ceramics, chemicals, glass, non-ferrous metals, pulp and paper and oil refineries.

Italy's energy-intensive industries emit around 76 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Italy could verify with industry which of the nine demonstrators reaching **TRL 6 to 8 before 2026** and funded under the **Horizon** framework programmes should be brought to first-of-a-kind level (TRL 9).

---

[47] This approximate total has been calculated by applying a pro rata amount for the multi-country projects that include several demonstrators.

[48] Hy2Use; complementary to the Hy2Tech for mobility applications.

Existing multi-country cooperation in relevant Horizon projects (**COGNIPLANT, CORALIS, ETEKINA, RETROFEED, SIMPLIFY, PLASTICE, Plastics2Olefins, PUSH2HEAT**) creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The **Innovation Fund** projects planning to demonstrate technologies close to market by 2025, could have proven their viability by then. They would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.11. Netherlands

Relevant demonstration projects, description and funding

The Netherlands has **11 demonstrators** for low-carbon technologies in energy-intensive industries that receive funding from EU instruments.

- **FirstBio2Shipping**: this project, coordinated by Attero, will develop the first industrial plant **converting biogas to renewable, low-carbon bio-liquefied natural gas** (bio-LNG). It has been awarded around **EUR 4.3 million** from the **Innovation Fund**. It is currently under construction and will be operational at **close-to-market** level **in 2023**. It will reduce emissions by 87,500 tonnes of CO_2-equivalent in greenhouse gases in its first 10 years of operation.

- **HFP**: this **electrification** project, coordinated by Saint-Gobain, is developing a first-of-a-kind hybrid furnace for **glass** wool production. It has been awarded around **EUR 4 million** in funding from the **Innovation Fund** and is expected to be **close to market** by **2025**. It has the potential to reduce emissions by 100,000 tonnes of CO_2-equivalent greenhouse gases in its first 10 years of operation.

- **Holland Hydrogen**: this project, coordinated by the Rotterdam Hydrogen Company with Shell as a beneficiary, plans to build a 400 megawatt electrolyser in the port of Rotterdam, to produce **green hydrogen**, using renewable electricity from offshore wind farms in the North Sea. It will be granted **EUR 89 million** from **the Innovation Fund** and will be operational **by 2027.** It will make it possible to reduce emissions by 5.1 million tonnes of CO_2 equivalent in greenhouse gases.

- **H2ermes**: this project, which was financed by a national contribution to an **IPCEI**, involves cooperation between HyCC, Tata Steel and the Port of Amsterdam to realise a 100 megawatt **hydrogen** factory in Ijmuiden. It is expected to begin operating **close to market** in **2027** and will abate 120,000 tonnes of CO_2 per year.

- **HyNetherlands**: this **industrial symbiosis** project aims to disseminate technologies, based on renewable **hydrogen**, that are being used to produce **e-methanol** in a newly built 100 MW electrolysis unit, together with biogenic CO_2 from a newly built **carbon-capture** plant. It is financed by a national contribution to the **H2Use IPCEI** and brings together three companies: Engie, OCI and EEW.

- **MultiPLHY**: this multi-country project, funded with around **EUR 7 million** from **Horizon 2020**, aims to operate the first high-temperature **electrolyser** system at a multi-megawatt-scale at the Neste **biofuels refinery** in Rotterdam to produce **hydrogen** for the refinery's processes. It is being developed at **TRL 9** and is expected to be operational by the end of **2024**.

- **ELECTRO**: this multi-country **plastic recycling** project, funded by **Horizon Europe** with around **EUR 14.2 million**, will demonstrate the electrified conversion of plastic waste into olefins (**circularity**). The project is expected to be ready at **TRL 7** by **2026**.

- **IMPRESS**: his multi-country project, coordinated by Avantium chemicals, is working on a novel **biorefinery** concept, which allows the conversion of plant-based non-food materials into important base **chemicals**. It will receive around **EUR 13.3 million** from **Horizon 2020** and will be operational at **TRL 6** in **2024**.

- **PERFORM**: this multi-country project is setting up a platform infrastructure for highly selective **electrochemical** conversions. It has received around **EUR 7.4 million** from **Horizon 2020** and is led by TNO. It is **already operational** at **TRL 6**.

- **ARAMIS:** this project, located on the Maasvlakte in the Port of Rotterdam, will offer a decarbonisation solution for industry by enabling the transport of CO_2 to depleted offshore gas fields under the North Sea (**CCUS**). It is expected to be ready by **2027** at **TRL 9** and could store 5 million tonnes of CO_2 per year.

- **UNIPER:** This project, operated by Uniper, involves the large-scale production of **green hydrogen** from offshore windfarms. It is planned to be operational by **2025** at **TRL 9**.

The four **Horizon** projects have or will demonstrate technologies at TRL 6 and 7, all before 2026. Private follow-up investment will be decisive if the technologies are to be brought to market.

The projects funded under the **Innovation Fund** are demonstrating technologies around green hydrogen, electrification and bio-liquefied natural gas that will be ready at high TRL by 2027.

Two projects financed by national contributions to a **IPCEI** concern the integration of renewable hydrogen.

The sectors covered by the demonstration projects in the Netherlands include fuel, chemicals and glass.

The Netherland's energy-intensive industries emit around 40 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

The Netherlands could verify with industry which of the technologies already demonstrated at (or reaching) TRL 6-8 before 2025 should be brought to the level of a first-of-a-kind plant (TRL 9). The existing cross-country cooperation in the relevant Horizon projects creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The demonstrators funded under the **Innovation Fund**, demonstrating technologies at high TRL could have proven their viability by 2027. They would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.12. Austria

Relevant demonstration projects, description and funding

Austria has **ten demonstrators for low-carbon technologies in energy-intensive industries** that receive funding under EU instruments.

- **BOREALIS**: this project, funded in the framework of the **IPCEI Hy2Use**, aims to use **green hydrogen** to produce fertilisers, melamine and technical nitrogen at Borealis' operations in Linz. It is expected to be operating at **close to market** level **in 2025** and aims to save 90,000 tons of CO_2 emissions per year.

- **HYFOR**: this project by Primetals Technologies has developed a **hydrogen**-based fine-ore reduction (HYFOR) pilot plant at the Voestalpine **steelworks** in Donawitz. It is **operational** at **TRL 6**.

- **H2FUTURE**: this multi-country **green hydrogen** project consists of a demonstration of a 6MW electrolysis power plant at the Voestalpine **steel** company in Linz, which is **operational** at **TRL 6**. It has received around **EUR 12 million** from **Horizon 2020**.

- **INEVITABLE:** this multi-country project, which will receive around **EUR 5.3 million** from **Horizon 2020**, aims to optimise manufacturing processes in **metal** industries by fully **digitalising** monitoring technology. In Austria, Voestalpine participates, and the demonstrators are expected to enter into operation at **TRL 7** in **2023**. The project aims to reduce CO_2 emissions by 3.0 to 3.5 kg per tonne of final product.

- **COGNIPLANT**: this multi-country project, with funding of around **EUR 6.7 million from Horizon 2020**, will supply plants with a **control system** to supervise the production process and its energy and resource needs. The Hermes Schleifmittel **chemical** plant is participating from Austria. The results of the project will be operational **in 2023 at TRL 7,** with the potential to reduce greenhouse gas emissions by 18%.

- **DryFiciency**: this multi-country project, with around **EUR 5 million** of funding from **Horizon 2020**, demonstrates **waste heat recovery** in industrial drying processes, including at Wienerberger, a **brick and ceramics** company in Austria. It is **already operational at TRL 7**.

- **MEGASYN:** this multi-country project plans the first demonstration of syngas production by co-electrolysis on the mega-watt scale in an industrial environment at the OMV Schwechat **refinery** in Austria. The project has received around **EUR 5 million** in funding from **Horizon 2020** and will lift the technology from TRL 5 to **TRL 7** by **2025**.

- **MORSE:** this multi-country project is demonstrating **digitalisation** technologies already operational at **TRL 7** in the **steel** industry and has received around **EUR 4.7 million** from **Horizon 2020.** In **Austria**, the project is taking place in the MFL steel plant.

- **PLASTICE**: this multi-country project, supported by **Horizon Europe** with around **EUR 15.1 million** in funding**,** is developing a set of new valorisation processes for **chemical recycling** technologies. Demonstrators are expected to be operational at **TRL 7** in **2026**.

- **Plastics2Olefins**: This multi-country project, which has received around **EUR 18 million** from **Horizon Europe**, aims to demonstrate a novel process to recycle plastics into high-value materials. It is expected to be operational at **TRL 7** by **2027**.

Most of the **Horizon** projects have or will demonstrate technologies at TRL 6 and 7 before 2026. Private follow-up investment will be decisive if technologies developed by the projects are to be brought to market.

The demonstrators at TRL 6 to 7 are developing technologies around **energy efficiency, the green hydrogen integration, renewable energy integration, digitalisation, circularity and resource efficiency**. There are **no electrification or carbon storage** demonstration projects to our knowledge.

The BOREALIS project demonstrates a **green hydrogen** integration technology which could be at the level of close to market by 2025.

The sectors covered by the demonstration projects in Austria are steel, cement, chemicals, oil refineries and ceramics.

Austria's energy-intensive industries emit around 24 million tonnes of CO_2-equivalent in greenhouse gases annually.

Conclusions

Austria could verify with industry which technologies already demonstrated at (or reaching) TRL 6-8 before 2025 should be brought to the level of a first-of-a-kind plant (TRL 9).

The existing multi-country cooperation in relevant Horizon 2020 projects creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The **BOREALIS** project, which is demonstrating close-to-market technologies, could have proven its viability by 2025. It would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of its technology throughout the EU.

3.13. Poland

Relevant demonstration projects, description and funding

Three demonstrators for low-carbon technologies in energy-intensive industries receive a total amount of EUR 235 million in EU funding.

- **GO4ECOPLANET** received EUR 228 million under the **Innovation Fund** (total project cost EUR 2.6 billion). Located in Bielawy, this first-of-a-kind in the **cement** industry will demonstrate a **CCUS technology**, It is planned to enter into operation in 2027 and aims to save 10 million tonnes of CO_2-equivalent in greenhouse gases during its first 10 years of operation.

- **Novum** (a pilot line based on novel manufacturing technologies for cellulose-based electrical insulation components) has received EUR 6.5 million from **Horizon 2020** (total cost of EUR 8 million). Located in the region of Krakow, it is already operational

at TRL 6, demonstrating a technology around the green hydrogen integration in the **pulp and** paper industry.

- **ACCSESS** (Providing access to cost-efficient, replicable, safe and flexible CCUS): this multi-country project demonstrates **CCUS** in the **cement** industry and has received EUR 15 million in total funding from **Horizon 2020**. Located in the Heidelberg plant in Opole, the demonstrator is planned to reach **TRL 7 in 2023.** The other two are located in Sweden and Spain, in the pulp and paper and glass industries.

Conclusions

Poland's energy-intensive industries emit around 51 million tonnes of CO_2-equivalent in greenhouse gases per year.

Poland could verify with industry whether the technologies already at or reaching TRL 6 or 7 before 2025 should be brought to the level of a first-of-a-kind plant (TRL 9).

The project Go4ecoplanet, which is demonstrating close-to-market technologies, would benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of its technology throughout the EU.

3.14. Portugal

Relevant demonstration projects, description and funding

Portugal has **five demonstrators** for low-carbon technologies in energy-intensive industries that are funded under an EU instrument.

- **CCL** (Clean Cement Lime): this demonstrator, located in the Lisbon region, has received EUR 14 million in EU funding from the **ERDF**, contributing to the project's total cost of EUR 86 million. The **cement** company SECIL will demonstrate waste heat energy recovery technologies (**energy efficiency**) **close to market by 2023**.

- **H2Enable** (the Hydrogen Way for Our Chemical Future): this EUR 142 million project located in the region of Estarreja is being funded under the **Hydrogen IPCEI**[49] to develop a **hydrogen integration** technology in the **chemicals** industry. The demonstrator, hosted in a Bondalti plant, is planned to be **close to market in 2026**.

- **LK2BM** (conversion of a pulp mill fuel source to biomass): this project has received EUR 4.5 million from the **Innovation Fund** to demonstrate the conversion of the pulp mill's lime kiln from fossil fuel (natural gas) to biomass fuel (wood waste). Hosted by the company Navigator Pulp Setubal, the demonstrator is under construction and will be **close to market in 2025**. The technology is expected to reduce emissions by 185,000 tonnes of CO_2-equivalent in greenhouse gases during its first 10 years of operation.

- **RETROFEED** (implementation of a smart retrofitting framework in the process industry towards its operation with variable, biobased and circular feedstock): the consortium for this **Horizon 2020** project is developing a **circularity** technology that will reach **TRL 7 in 2023** in various energy-intensive industries in six different locations. In Portugal, the demonstrator is located in the Maceira-Liz region, hosted in the SECIL **cement** factory.

[49] Hy2Use; complementary to the Hy2Tech for mobility applications.

The project is also demonstrating this technology in the **ceramics, chemicals, steel, and aluminium** industries. It has received funding of EUR 9.9 million for a total project cost of EUR 15.6 million. Depending on the sector, energy use will be reduced by 17-22%, and greenhouse gas emissions by 17-30%.

- **EMB3Rs** (User-driven energy-matching and business prospection tool for industrial excess heat/cold reduction, recovery and redistribution): this **digitalisation** and **energy efficiency** tool has been demonstrated in the cement industry and has received EUR 4 million from **Horizon 2020**. It is already operational.

Portugal's demonstration projects are limited to technologies for **hydrogen integration** and **energy efficiency**. However, the sectors covered by the demonstration projects (at least partly) in Portugal cover several energy-intensive industries.

The **RETROFEED** demonstrator (described above) is at TRL 7. Private follow-up investment will be decisive if the technology is to be brought to market.

Portugal's energy-intensive industries emit around 12 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Portugal could verify with industry whether the demonstrator **RETROFEED,** currently at TRL 7, should be brought to first-of-a-kind level (TRL 9) by the end of 2026, in line with State aid rules, if considered feasible and appropriate by industry.

The existing cross-country cooperation in this project (other demonstrators funded under the same project are located in Spain, Italy, Romania and Turkey) creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The other demonstrators in Portugal, all close to market, could have proven their viability by 2025. They would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.15. Romania

Relevant demonstration projects, description and funding

Romania has **two demonstrators** for low-carbon technologies in energy-intensive industries that receive funding under EU instruments. Both are multi-country projects funded under **Horizon 2020**.

- **ConsenCUS** (Carbon-neutral clusters through electricity-based innovations in capture, utilisation and storage): located in Sud-Muntenia, this demonstrator for a **carbon capture** technology in the **oil refineries** sector at **TRL 7** is planned to be operational in 2025. Other demonstrators under the same project in Denmark and Greece will do the same in the cement and magnesite sectors. It has been granted a total of EUR 12.9 million in funding from **Horizon 2020**.

- **RETROFEED** (Implementation of a smart retrofitting framework in the process industry towards its operation with variable, biobased and circular feedstock): this demonstrator

located in Calarasi is under construction and should be operational in 2023. It aims to demonstrate a **circularity** technology in the **steel** sector at **TRL 7**. The other demonstrators under this project (which received a EUR 9.9 million grant from Horizon 2020) are located in Spain, Italy, Portugal and Turkey and cover the **cement**, **ceramics**, **chemicals** and **non-ferrous metals** industries.

Romania does not have any demonstration project, in the scope of this mapping, on **hydrogen integration** and **electrification**. However, the sectors covered by the demonstration projects located (at least partly) in Romania cover several energy-intensive industries.

The two demonstrators described above are at TRL 7. Private follow-up investment will be decisive if technologies are to be brought to market.

Romania's energy-intensive industries emit around 20 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Romania could verify with industry whether these two demonstrators at TRL 7 should be brought to first-of-a-kind level (TRL 9) in the coming years. The existing multi-country cooperation in these projects creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

3.16. Slovenia

Relevant demonstration projects, description and funding

Slovenia has **three demonstrators** for low-carbon technologies in energy-intensive industries that receive funding under EU instruments.

- **BEAR** (Hybrid regenerative glass furnace): located in Hrastnik, Zasavje, this project is demonstrating an **electrification** thermal process technology in the **glass** sector and has received **EUR 2.2 million** from the **Innovation Fund**. Demonstrated by the organisation Steklarna Hrastnik, the project is planned to be operational close to market in 2025, with the objective of saving 96,000 tonnes of CO_2 in its first 10 years of operation.

- **ETEKINA** (Heat pipe technology for thermal energy recovery in industrial applications): Located in Ravne na Koroškem, the Sij Metal Ravne plant (part of the Slovenian **steel** group) is demonstrating a **waste heat energy** recovery technology. The project is demonstrating this **energy efficiency** technology in two other locations, in Italy and Spain, in the cement and aluminium sectors, with total funding from **Horizon 2020** of **EUR 4.6 million** (the total cost of the project is EUR 5.5 million). The project is already **operational** at **TRL 7** and intends to reduce CO_2 emissions by 298 tonnes per year.

- **INEVITABLE** (Optimization and performance improving in metal industry by digital technologies): this project is demonstrating **digitalisation** technologies in the **steel** sector in three locations: Slovenia, Spain and Austria. The demonstrators are **under construction** and will reach **TRL 7 in 2023**. The project has received **EUR 5.3 million** in funding from **Horizon 2020**, for a total project cost of EUR 6.2 million. The estimated reduction in emissions will be between 3.0 kg and 3.5 kg CO_2 per tonne of final product, with an estimated total annual steel production of 1 million tonnes.

Slovenia does not have any demonstration project, in the scope of this mapping, on the green hydrogen integration or **carbon capture and storage**, although these technology pathways for climate neutrality are at the heart of REPowerEU, and Slovenia has expressed a strong interest in hydrogen.

The **ETEKINA** project on energy efficiency is at TRL 7. Private follow-up investment will be decisive if technologies are to be brought to market.

The sectors covered by the demonstration projects located (at least partly) in Slovenia concern the energy-intensive industries of **glass**, **steel**, **cement** and **aluminium**.

Slovenia's energy-intensive industries emit around 2 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Slovenia could verify with industry whether the two demonstrators at TRL 7 funded under Horizon 2020, **Etekina** and **Inevitable,** should be brought to first-of-a-kind level (TRL 9). The existing multi-country cooperation in these two projects creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The **Bear** project, funded under the Innovation Fund, aims to have proven its viability by 2025. It would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.17. Finland

Relevant demonstration projects, description and funding

Finland has **six demonstrators** for low-carbon technologies in energy-intensive industries that receive funding under EU instruments.

- **SHARC:** this **renewable hydrogen** project, receiving funding of **EUR 88 million** from **the Innovation Fund**, introduces electrolysis and carbon capture and storage solutions at Neste's **refinery** in Porvoo. It will operate at a **close-to-market** level in **2025** and a reduction of more than 4 million tonnes of CO_2-equivalent in greenhouse gases will be achieved in the first 10 years of operation.

- **PULSE:** this chemical **recycling** project aims to integrate technologies into the company's **refinery** in Porvoo. It will receive **EUR 135 million** from the **Innovation Fund**. The demonstrator is planned to be **close to market by 2028** and will cut 10.3 million tonnes of CO_2-equivalent in greenhouse gases during its first 10 years of operation.

- **MORSE:** this multi-country project demonstrates digitalisation technologies at **TRL 7** in the **steel** industry in **two plants in Finland** (and one in Austria), which are already operational. It has received **EUR 4.7 million** from **Horizon 2020.**

- **P2X-Europe**: this project demonstrates power-to-liquid technology solutions from renewable energy-derived **hydrogen** in the **chemicals** sector. Finland is contributing **EUR 70 million** to this demonstrator in Harjavalta, which will be **close to market in 2024,** through the **Hydrogen IPCEI**.

- **Innomost Oy** is building a pilot plant for production in Kokkola, which aims to manufacture raw materials for the **cosmetics industry** from the side streams of the forest industry and further products for other areas of industrial application. This **industrial symbiosis** project received **EUR 249,780** from the **ERDF** and is already **operational**.

The two demonstrators under the **MORSE** project are already operational at TRL 7. Private follow-up investment will be decisive if technologies are to be brought to market.

The **SHARC, P2X-Europe and Innomost Oy** projects will get close to market by 2025 and **PULSE** by 2028.

The sectors covered by the demonstration projects in Finland concern the steel, chemicals and refinery sectors.

Finland's energy-intensive industries emit around 11 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Finland could verify with industry which of the technologies demonstrated at TRL 7-8 and funded under **Horizon** framework programmes could be brought to the level of first-of-a-kind plants (TRL 9).

The two demonstrators under the **MORSE** project are already operational at TRL 7. The existing multi-country cooperation in this project create a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The **SHARC** and **PULSE** demonstrators**,** which aim to get close to market, could have proven their viability by 2025. They would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.18. Sweden

Relevant demonstration projects, description and funding

Sweden has **ten** demonstrators for low-carbon technologies in energy-intensive industries that receive funding under EU instruments.

- **HIYIELD**: this project aims to promote **circularity** by progressively increasing **scrap uptake** in three scenarios that represent the current European **steelmaking** methods. Kungliga Tekniska Hoegskolan acts as the main coordinator for this multi-country project, which will receive around **EUR 3.6 million** from **Horizon Europe.** It will be developed to **TRL 8 by 2025**.

- **ACCSESS**: this multi-country project, which will receive around **EUR 15 million** from **Horizon 2020**, provides access to cost-efficient, replicable, safe and flexible **CCUS**. In Sweden, Stora Enso is involved at a **pulp and paper** mill in the province of Uppland. The demonstrator will be operational **in 2025 at TRL 7**.

- **CORALIS:** this multi-country project, which has received funding of around **EUR 18 million** from **Horizon 2020**, is demonstrating the utilisation of **CO_2** and **low-grade**

waste heat. In Sweden: the Höganäs (steel industry) **symbiosis** network is taking part. It will be operational **in 2024 at TRL 7** and is expected to reduce CO_2 emissions by 25-50%.

- **AIR:** located in Stenungsund, this project demonstrates the production of sustainable methanol as a raw material for **chemical** products through a first-of-a-kind **carbon capture** and utilisation process integrated with a global-scale electrolysis unit. It will receive **EUR 97 million** from the **Innovation Fund**. Demonstrated by the organisations Perstorp Group and Uniper, the project is planned to be operating **close to market in 2027** and will reduce CO_2 emissions by 500,000 tonnes per year.

- **BECCS:** this project will create a world-class, full-scale bio-energy **carbon capture and storage** facility at Stockholm Exergi's heat and power biomass plant. The **Innovation Fund** will allocate **EUR 180 million** to the project for a planned date of entry into operation at **close to market level in 2026**. The project has the potential to remove around 7 million tonnes of emissions of CO_2 equivalent in greenhouse gases in its first ten years of operation.

- **HYBRIT**: this project, driven by SSAB, LKAB and Vattenfall, has received **EUR 143 million** from the **Innovation Fund** for an industrial- and commercial-scale demonstration of a complete value chain for **hydrogen**-based manufacturing of **iron and steel**, from the mine to fossil-free steel. The project will be operating at **close to market** level **in 2027** and has the potential to remove 14.3 million tonnes of CO_2-equivalent in greenhouse gas emissions in its first ten years of operation.

- **TFFFTP**: this project, coordinated by Essity Operations Sweden, replaces liquefied natural gas (LNG) used to dry the paper at a **paper** production facility at Lilla Edet with bio-syngas generated in a new on-site gasification plant using wood waste. The **Innovation Fund** will grant **EUR 4.2 million** to the project, which will begin operating at **close to market** level **in 2025** and will cover the steam and heat needed for 69,000 tonnes of annual paper production.

- **Thermoplastic Lignin Production (TLP)**: this project, located in Sundsvall, is developing a first-of-a-kind **biorefinery** that produces a completely new renewable and biodegradable biomaterial from lignin, a by-product of the kraft **pulping industry**. It receives around **EUR 4.4 million** from the **Innovation Fund** and is expected to be operational **in 2024** at **close to market level**.

- **HySkies**: this project is building the first large-scale **synthetic sustainable** aviation **fuel** (SAF) production facility (oil refinery). **Fossil-free hydrogen** from a 200 megawatt electrolyser, biogenic CO_2 captured from a waste-to-energy plant, and sustainable ethanol will be fed into a two-step process consisting of gas fermentation and alcohol-to-jet. It will result in a 94% reduction in CO_2 emissions in its first ten years of operation. It will receive **EUR 80.2 million** from the **Innovation Fund** and will begin operating **close to market** in **2027**.

- **H2 Green Steel:** this project, located in Boden, creates a **hydrogen**-based integrated primary **steel** manufacturing plant encompassing innovative first-of-a-kind commercial-scale components. Partly funded by **InvestEU**, it will be ready at **close to market** level in **2026** and will reduce CO_2 emissions by 35 million tonnes per year.

The projects **HIYIELD, ACCSESS and CORALIS** will be at TRL 7 and 8 by 2025 and will need private investment to be brought to market.

The remaining projects should reach TRL 9 by 2026/2027.

The sectors covered by the demonstration projects located (at least partly) in Sweden concern most energy-intensive industries, including **steel** and **iron**, **pulp** and **paper**, and **chemicals**.

Sweden's energy-intensive industries emit around 13 million tonnes of CO_2-equivalent in greenhouse gases per year.

Conclusions

Sweden could verify with industry which of the technologies already demonstrated at (or reaching) TRL 6-8 should be brought to the level of a first-of-a-kind plant (TRL 9). The existing multi-country cooperation in all these projects creates a basis for potential future cooperation on leveraging follow-up investments to bring technologies to market.

The projects already aiming to be close to market could prove their viability in the coming years. They would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of their technology throughout the EU.

3.19. Iceland

There is one demonstrator for low-carbon technologies in energy-intensive industries in Iceland that receives funding under EU instruments:

Silverstone, an **Innovation Fund** project, is the successor to the Horizon 2020-funded Carbfix project. The project involves the design, construction and commissioning of a plant that dissolves CO_2in water as it flows into subsurface basalt rocks, where it is fixed into stable carbonates. This process is known as **carbon capture** and mineral storage (CCMS). The project will bring CCMS, which is not yet commercialised elsewhere, to **full commercial scale**. The project has received a grant of **EUR 3.9 million** and aims to capture around 34,000 tonnes of CO_2per year, avoiding almost **100% of the greenhouse gas emissions** produced by a conventional technology. The new carbon capture plant will be commissioned in **2025.**

This project could prove its viability by 2025. It would then benefit from favourable framework conditions in terms of the availability of skills and infrastructure and could facilitate a wider application of the technology throughout the EU.

3.20. Norway

Norway has **six demonstrators** for low-carbon technologies in energy-intensive industries that are funded under an EU instrument.

- **ACCSESS**: this multi-country project, which will receive around **EUR 15 million** from **Horizon 2020**, provides access to cost-efficient, replicable, safe and flexible **CCUS**. The demonstrator in Oslo operates in the pulp and paper and cement industries and will be operational **in 2025 at TRL 7**.

- **BIOZIN:** this project aims to build the world's first commercial-scale **drop-in biofuel** (i.e., **renewable hydrocarbon biofuels** that are compatible with the fuel infrastructure)

production facility in Amli, Norway. It will receive **EUR 75 million** from the **Innovation Fund** and will be operational at **TRL 9** by **2026**.

- **LIBERATE:** This multi-country project, which has received around **EUR 8.8 million** from **Horizon 2020**, aimed to convert low-cost lignin **feedstock from wood** into high-value and **sustainable chemicals** through an electrochemical process. It is already operational at TRL 6.

- **MOF4AIR** (Metal organic frameworks clean carbon dioxide from our atmosphere): This multi-country project, which received **EUR 9.9 million** from **Horizon 2020**, develops and demonstrates the performances of MOF-based CO_2 **capture technologies** in power plants and energy-intensive industries. It is expected to enter into operation at **TRL 6** in **2023**.

- **PYROCO2** (Creating value from industrial CO2 sources): This multi-country project, which receives **EUR 40 million** from **Horizon 2020**, demonstrates sustainable value creation from industrial CO_2 by its thermophilic microbial conversion into acetone. Coordinated by Sintef, it will be operational at **TRL 7** in 2026.

- **REALISE:** This multi-country project demonstrates a **CCUS** technology. The demonstrator in Norway is located in Trondheim and operates in the **chemicals** industry. The project received around **EUR 6.4 million** funding from **Horizon 2020** and is already operational at **TRL 6**.

3.21. Turkey

Turkey has **two** demonstrators for low-carbon technologies in energy-intensive industries that receive funding under EU instruments.

- **BAMBOO**: this multi-country project is developing new approaches to flexibility management by optimising the off-gas and waste use process for greater **energy efficiency** in **oil refineries**. The project has received around **EUR 10.4 million** from **Horizon 2020** and is **already operational** at **TRL 7**. In Turkey, the demonstrator is located in Aliağa.

- **RETROFEED** (Implementation of a smart retrofitting framework in the process industry towards its operation with variable, biobased and circular feedstock): this demonstrator located in Akyazı, in Sakarya province, is under construction and should be operational in 2023. It intends to demonstrate a **circularity** technology in the **aluminium** sector at **TRL 7**. The other demonstrators under this project (which received a EUR 9.9 million grant under Horizon 2020) are located in Spain, Italy, Portugal and Romania and cover the steel, cement, ceramics and chemicals industries.

Turkey could verify with industry which of the technologies aiming for or already at TRL 7 should be brought to the level of a first-of-a-kind plant (TRL 9). Existing cross-country cooperation in these projects creates a basis for potential future cooperation in leveraging follow-up investments to bring technologies to market.

3.22. Annex: detailed list of demonstrators for relevant countries

Project acronym	Project title	Funding instrument	Technology group	Sectors	Organisation name	Region	TRL	Status & expected date of entry into operation
BELGIUM								
C4U	Advanced Carbon Capture for steel industries integrated in CCUS Clusters	H2020	CCUS	Steel	ArcelorMittal	Ghent	TRL 7	Under construction / 2024
CAESAR	CirculArity Enhancements by Low quality Scrap Analysis and Refinement	Horizon Europe	circularity	Steel	ArcelorMittal	Ghent	TRL 8	Feasibility / 2026
CO2Fokus	CO2 utilisation focused on market relevant dimethyl ether production, via 3D printed reactor- and solid oxide cell-based technologies	H2020	CCUS	Chemicals, oil refineries, cement	Vito	Flanders	TRL 6	Under construction / 2023
CO2ncrEAT	Integrated low carbon footprint solution for cement-free building products by using exhaust CO2 gas from lime manufacturing plant and wasted by-product from stainless steel production	Innovation Fund	CCUS	Cement, steel	Fluxys	Liege	Close to market	Planned / 2025
ENGIE	ENGIE	IPCEI	Hydrogen integration	Steel	John Cockerill,Engie	Charleroi	Close to market	Planned / 2030
INITIATE	Innovative industrial transformation of the steel and chemical industries of Europe	H2020	CCUS	Steel, chemicals	ArcelorMittal		TRL 8	Planned / 2030
Kairos@C	Building strong momentum for massive decarbonisation in the EU through a unique end-to-end CCS	Innovation	CCUS	Chemicals	Air	Antwerpen	Close to	Planned / 2030

	project	Fund			Liquide,BASF		market	
ReActiv	Industrial Residue Activation for sustainable cement production	H2020	circularity	Non-ferrous metals, cement	KU Leuven	Leuven	TRL 7	Operational
RecHycle	Recycling renewable hydrogen for climate neutrality	Horizon Europe	Hydrogen integration	Steel	ArcelorMittal		TRL 8	Feasibility / Unknown
STEELANOL	Production of sustainable, advanced bio-ethANOL through an innovative gas-fermentation process using exhaust gases emitted in the STEEL industry	InnovFin & H2020	CCUS	Steel	ArcelorMittal	Ghent	TRL 7	Operational
Torero	TORrefying wood with Ethanol as a Renewable Output: large-scale demonstration	InnovFin & H2020	circularity	Steel	ArcelorMittal	Ghent	TRL 7	Operational
Germany								
BAMBOO	Boosting new Approaches for flexibility Management By Optimizing process Off-gas and waste use	H2020	energy efficiency	Pulp, paper and cardboard	UPM		TRL 7	Already operational
ECCO	Energy Efficient Coil Coating Process	H2020	electrification	Steel	Karlsruher Institut fur Technologie		TRL 6	Already operational
ECO2Fuel	Large-scale low-temperature electrochemical co2 conversion to sustainable liquid fuels	H2020	electrification	Chemicals	RWE	Essen	TRL 7	Planned / 2026
GrInHy 2.0	Green Industrial Hydrogen via steam electrolysis	H2020	green hydrogen integration	Steel	Salzgitter Sunfire GmBH	SalzGitter	Close to market	Under construction / 2023

intelWATT	intelligent Water Treatment Technologies for water preservation combined with simultaneous energy production and material recovery in energy intensive industries	H2020	circularity	Chemicals	BIA Group	North-Westfalia/Solingen	TRL 7	Planned / 2024
LEILAC-2	LOW EMISSIONS INTENSITY LIME AND CEMENT 2: DEMONSTRATION SCALE	H2020	CCUS	Cement	Heidelberg	Hanover	Close to market	Construction starting in 2023
MefCO2	Synthesis of methanol from captured carbon dioxide using surplus electricity	H2020	CCUS	Multiple	Niederaussem plant, run in cooperation between MHPSE and RWE	Rhein-Erft-Kreis/Bergheim	TRL 6	Already operational
			energy efficiency				TRL 7	
MMAtwo	Second generation Methyl MethAcrylate (MMAtwo)	H2020	circularity	Chemicals	Heathland & JSW Europe	Dusseldorf	TRL 7	Unknown
PreMa	Energy efficient, primary production of manganese ferroalloys through the application of novel energy systems in the drying and pre-heating of furnace feed materials.	H2020	energy efficiency	Non-ferrous metals	MINTEK and Outotec GmbH	Frankfurt	TRL 7	Operational
PRODIAS	PROcessing Diluted Aqueous Systems	H2020	resource efficiency	Chemicals	BASF	Rhineland-Palatinate/Ludwigshafen	TRL 7	Operational
			resource efficiency	Chemicals	CARGILL HAUBOURDIN	North Rhine-Westphalia/Krefeld	TRL 7	Operational
			resource efficiency	Chemicals	UPM-KYMMENE (UPM)		TRL 7	Concept
REFHYNE	Clean Refinery Hydrogen for Europe	H2020	green hydrogen	Oil refineries		Wasseling	TRL 7	Operational

			integration					
REVaMP	Retrofitting equipment for efficient use of variable feedstock in metal making processes	H2020	circularity	Steel	ArcelorMittal Bremen	Bremen	TRL 7	Under construction
FLEXIndustries	Digitally-enabled FLEXible Industries for reliable energy grids under high penetration of Variable Renewable Energy Sources	Horizon Europe	energy efficiency	Pulp, paper and cardboard	PRO	Eisenhüttenstadt	TRL 7	Planned
MaxH2DR	Maximise H2 Enrichment in Direct Reduction Shaft Furnaces	Horizon Europe	green hydrogen integration	Steel	VDEH-Betriebsforschungsinstitut GMBH (BFI) & Ruhr-Universität Bochum		TRL 8	Feasibility
PUSH2HEAT	Pushing forward the market potential and business models of waste heat valorisation by full-scale demonstration of next-gen heat upgrade technologies in various industrial contexts.	Horizon Europe	energy efficiency	Pulp, paper and cardboard	STC	Weissenborn	TRL 7	Under construction / 2026
C2B	Carbon2Business	Innovation Fund	CCUS	Cement	Holcim	Laegerdorf	Close to market	Planned / 2028
DRIBE	DRIBE	National programme	green hydrogen integration	Steel	Arcelor Mittal	Bremen and Eisenhuttenstadt	Close to market	Planned / 2030
H2Hamburg	Working towards the production of zero-carbon emissions steel with hydrogen	National programme including link to IPCEI	green hydrogen integration	Steel	ArcelorMittal	Hamburg	~TRL 7	Under construction / 2025
Westkueste100 phase 1	Green hydrogen and decarbonisation on an industrial scale	National programme including link to IPCEI	green hydrogen integration	Multiple	cross-industry partnership “Westküste 100”	Schleswig-Holstein	Close to market	Under construction / 2025

Project acronym	Project title	Funding instrument	Technology group	Sectors	Region	Cross-country project?	TRL	Status & expected date of entry into operation
SPAIN								
BAMBOO	Boosting new Approaches for flexibility Management By Optimizing process Off-gas and waste use	H2020	energy efficiency	Steel	Aviles	Yes	TRL 7	Already operational
COGNIPLANT	Cognitive platform to enhance 360° performance and sustainability of the European process industry	H2020	digitalisation	Steel	Amurrio (Alava)	Yes		Unknown / 2023
CORALIS	Creation Of new value chain Relations through novel Approaches facilitating Long-term Industrial Symbiosis	H2020	industrial symbiosis	Chemicals	Murcia/ Cartagena	Yes	TRL 7	Planned / 2024
DESTINY	Development of an Efficient Microwave System for Material Transformation in energy INtensive processes for an improved Yield	H2020	energy efficiency	Cement, ceramics, steel, iron			TRL 6	Already operational
ETEKINA	Heat pipe technology for thermal energy recovery in industrial applications	H2020	energy efficiency	Aluminium	Eskoriatza, Gipuzkoa	Yes	TRL 7	Already operational
HyperCOG	Hyperconnected Architecture for High Cognitive Production Plants	H2020	digitalisation	Steel, cement, chemicals				Unknown / 2023
iCAREPLAST	Integrated Catalytic Recycling of Plastic Residues Into Added-Value Chemicals	H2020	circularity	Chemicals (plastics)	Aragon/Zaragoza		TRL 7	Already operational
INEVITABLE	Optimization and performance improving in metal industry by digital technologies	H2020	digitalisation	Steel		Yes	TRL 7	Under construction / 2023
intelWATT	intelligent Water Treatment Technologies for water preservation combined with simultaneous energy production and material recovery in EII	H2020	circularity	Multiple	Barcelona/ Catalonia	Yes	TRL 7	Planned / 2024
REHAP	Systemic approach to Reduce Energy demand and CO2 emissions of processes that transform agroforestry waste into High Added value Products.	H2020	circularity	Chemicals (bulk organic chemicals)	Galicia		TRL 7	Already operational

RESLAG	Turning waste from steel industry into a valuable low-cost feedstock for EII	H2020	resource efficiency	Steel, refractory ceramics			TRL 7	Already operational
RETROFEED	Implementation of a smart RETROfitting framework in the process industry towards its operation with variable, biobased and circular FEEDstock	H2020	energy efficiency	Ceramics	Comunidad Valenciana/ Alcora	Yes	TRL 7	Under construction / 2023
			circularity	Chemicals (fertilisers)	Andalucia / Huelva	Yes	TRL 7	Under construction / 2023
REVaMP	Retrofitting equipment for efficient use of variable feedstock in metal making processes	H2020	energy efficiency	Non-ferrous metals (aluminium)	Basque Country	Yes	TRL 7	Under construction / 2023
REVaMP	Retrofitting equipment for efficient use of variable feedstock in metal making processes	H2020	circularity	Non-ferrous metals (aluminium)	Castilla y Leon	Yes	TRL 7	Under construction / 2023
					Catalonia	Yes	TRL 7	2023
			circularity	Steel	Basque Country	Yes	TRL 7	2023
FLEX4FACT	Industrial Cluster FLEXibility platform for sustainable FACTories to reduce CO2 emissions and to enable the Energy Transition	Horizon Europe	digitalisation	Chemicals (plastics)			TRL 7	Feasibility / 2025
			digitalisation	Steel			TRL 7	2025
PLASTICE	New technologies to integrate PLASTIC waste in the Circular Economy	Horizon Europe	circularity	Chemicals (plastics, textile, bulk organic chemicals)	Zaragoza	Yes	TRL 7	Feasibility / 2026
Plastics2Olefins	Recycling plastic waste into high-value materials-Closing the Loop	Horizon Europe	circularity	Chemicals (plastics)	Aragon/Zaragoza	Yes	TRL 7	Planned / 2027
TRINEFLEX	Transformation of energy intensive process industries through integration of energy, process, and feedstock flexibility	Horizon Europe	digitalisation	Non-ferrous metals (aluminium)	Alava	Yes	TRL 7	Feasibility / 2026
AGGREGA	Fabrication of CO2 negative AGGREGAtes based on disruptive accelerated carbonation processes fuelled	Innovation	CCUS	Glass, ceramics	Vizcaya		Close-to-	Under construction /

CO2	by carbon capture in refineries	Fund					market	2024
CIRQLAR	Low temperature heat recovery and upgrade for industrial use by heat pumps	Innovation Fund	energy efficiency	Oil refineries	Galicia		Close-to-market	Planned / 2025
CLYNGAS	FOAK technology to Substitute petroleum coke in the cement industry by synthesis gas (syngas) generated from gasification of stabilised refused derived fuels	Innovation Fund	green hydrogen integration	Cement	Valenciana		Close-to-market	Planned / 2025
ECOPLANTA	Reduction of CO2 Emissions from municipal non-recyclable waste to produce methanol	Innovation Fund	green hydrogen integration	Chemicals (bulk organic chemicals)	Tarragona		Close-to-market	Planned / 2026
SKFOAAS	SKF RECONDOIL AS A SERVICE	Innovation Fund	circularity	Chemicals, oil refineries			Close-to-market	Under construction / 2023
W4W	Waga 4 World	Innovation Fund	circularity	Chemicals (bulk organic chemicals)	Spain		Close-to-market	2023
BH2C	Basque Hydrogen Corridor	National programme including link to IPCEI	green hydrogen integration	Oil refineries	Bilbao		Close-to-market	Planned / 2024
COBRA	COBRA	IPCEI	green hydrogen integration	Cement, ceramics, chemicals	Cartagena, Castellon		Close-to-market	Under construction / 2023
IAM Caecius, H2 Abono, H2 Los Barrios	IAM Caecius, H2 Abono, H2 Los Barrios	IPCEI	green hydrogen integration	Multiple	Teruel, Asturias and Cadis (3 electrolysers in total)		Close-to-market	Planned / Unknown

IBERDROLA	IBERDROLA	IPCEI	green hydrogen integration	Chemicals	Puertollano		Close-to-market	Under construction / 2027

Project acronym	Project title	Funding instrument	Technology group	Sectors	Organisation name	Region	TRL	Status & expected date of entry into operation
FRANCE								
BCP	Batch and Cullet Preheating technology first-of-a-kind, commercial-scale demonstration towards decarbonization of flat glass production	Innovation Fund	energy efficiency	Glass	Saint Gobain	Aniche	Close to market	Under construction / 2025
C2FUEL	Carbon Captured Fuel and Energy Carriers for an Intensified Steel Off-Gases based Electricity Generation in a Smarter Industrial Ecosystem	H2020	CCUS	Steel	ArcelorMittal		TRL 7	Under construction / 2023
CAESAR	CirculArity Enhancements by Low quality Scrap Analysis and Refinement	Horizon Europe	circularity	Steel	ArcelorMittal	Dunkirk	Close to market	Feasibility / 2026
CalCC	First industrial-scale CC for lime production integrated with shared pipeline transport of dense phase CO2 to coastal hub for shipping to geological storage in the North Sea	Innovation Fund	CCUS	Cement	Air Liquide	Rety	Close to market	Planned / 2027
3D	DMX Demonstration in Dunkirk	H2020	CCUS	Steel	IFP Energies nouvelles	Dunkirk	Close to market	Operational
EB UV	EB/UV curing without GasSearch for available translations of the preceding	Innovation Fund	electrification	Steel	Arcelo Mittal Construction	Contrisson	Close to market	Under construction / 2023

K6 Program	K6 Program	Innovation Fund	CCUS	Cement	AIR LIQUIDE	Lumbres	Close to market	Planned / 2028
MassHylia	MassHylia	IPCEI	green hydrogen integration	Oil refineries	ENGIE, Total Energies	Marseille	Close to market	Planned / 2026
SIDERWIN	Development of new methodologies for industrial CO2-free steel production by electrowinning	H2020	electrification	Steel	Arcelormittal Maizieres Research	Metz	TRL 6	Operational
SIMPLIFY	Sonication and Microwave Processing of Material Feedstock	H2020	electrification	Chemicals	ARKEMA	Lacq	TRL 6	Operational
		H2020	electrification	Chemicals	COATEX	Lyon, Genay	TRL 6	Operational
SUPREME	Sustainable and flexible powder metallurgy processes optimisation by a holistic reduction of raw material resources and energy consumption	H2020	digitalisation	Steel, non-ferrous metals	OUTOTEC; ASL; and GKN		TRL 7	Operational
TRINEFLEX	Transformation of energy intensive process industries through integration of energy, process, and feedstock flexibility	Horizon Europe	digitalisation	Glass	Verallia Group		TRL 7	Feasibility / 2026
WHIN	Waste Heat recovery in silicon INdustry	ERDF	energy efficiency	Chemicals	Dalkia and Ferropem	Auvergne-Rhône-Alpes	TRL 7-8	Operational
Italy								
CLEANKER	CLEAN clinKER production by Calcium looping process	H2020	CCUS	Cement	Buzzi Unicem	Emilia-Romagna	TRL 7	Under construction / 2030
COGNIPLANT	COGNITIVE PLATFORM TO ENHANCE 360° PERFORMANCE AND SUSTAINABILITY OF THE EUROPEAN PROCESS INDUSTRY	H2020	digitalisation	Cement	Fornaci Calce Grigolin	Ponte della Priula	TRL 7	Under construction / 2023

CORALIS	Creation Of new value chain Relations through novel Approaches facilitating Long-term Industrial Symbiosis	H2020	circularity	Non-ferrous metals, steel	Rina Consulting Centro Sviluppo Materiali Spa	Lombardy/Brescia	TRL 7	Planned / 2024
ETEKINA	Heat pipe technology for thermal energy recovery in industrial applications	H2020	energy efficiency	Cement	CERAMICHE ATLAS CONCORDE S.P.A (CON)	Modena	TRL 7	Already operational
FACTLOG	Energy-aware Factory Analytics for Process Industries	H2020	energy efficiency	Oil refineries, Steel	MAGGIOLI SPA		TRL 7	Unknown / 2023
iWAYS	Innovative WAter recovery Solutions through recycling of heat, materials and water across multiple sectors	H2020	energy efficiency	Ceramics	CERAMICHE ATLAS CONCORDE SPA	Emilia-Romagna/Modena	TRL 7	Planned / 2024
RETROFEED	Implementation of a smart RETROfitting framework in the process industry towards its operation with variable, biobased and circular FEEDstock	H2020	circularity	Steel	FENO	Friuli	TRL 7	Under construction / 2023
SIMPLIFY	Sonication and Microwave Processing of Material Feedstock	H2020	electrification	Chemicals, ceramics	COLOROBBIA CONSULTING	Florence / Sovigliana	TRL 6	Already operational
SO WHAT	Supporting new Opportunities for Waste Heat And cold valorisation Towards EU decarbonization	H2020	energy efficiency	Chemicals, non-ferrous metals, steel			TRL 8	Already operational
H2GLASS	H2GLASS	Horizon Europe	green hydrogen integration	Glass, non-ferrous metals	Steklarna, Owens Corning, Zignago Vetro, Vetrobalsamo and Hydro		TRL 7	Feasibility / 2027
PLASTICE	New technologies to integrate PLASTIC waste in the Circular Economy	Horizon Europe	circularity	Chemicals	Rina Consulting Centro Sviluppo Materiali SP	Rome	TRL 7	Feasibility / 2026

Plastics2Olefins	Recycling plastic waste into high-value materials- Closing the Loop	Horizon Europe	circularity	Chemicals	CSM	Rome	TRL 7	Planned / 2027
PUSH2HEAT	Pushing forward the market potential and business models of waste heat valorisation by full-scale demonstration of next-gen heat upgrade technologies in various industrial contexts	Horizon Europe	energy efficiency	Pulp, paper and cardboard	CDG	Lazio	TRL 7	Under construction / 2026
ReMFra	REcovering Metals and Mineral FRAction from steelmaking residues	Horizon Europe	energy efficiency	Steel	Tenaris Dalmine nd Montanuniversit aet Leoben	Lombardia	TRL 8	Feasibility / 2026
H2 Valcamonica	H2 Valcamonica: Green hydrogen for the decarbonisation of Valcamonica	Innovation Fund	green hydrogen integration	Multiple	A2A	Brescia	Close to market	Planned / 2025
PRIMUS	PRIMUS: Prime Manufacturing of crystal glass under innovative Solution	Innovation Fund	energy efficiency	Glass	Bormioli Rocco	Emilia-Romagna	Close to market	Planned / 2023
VITRUM	VITRUM: Virtuous Innovative Transformation of high-quality container glass manufacturing	Innovation Fund	electrification	Glass	Bormioli Luigi	Lombardia	Close to market	Planned / 2024
HYDRA-ITALIA	HYDRA-ITALIA (L1, L2 and L3)	IPCEI	green hydrogen integration	Steel	RINA-CSM	Umbria, Puglia, Calabria	Close to market	Planned / 2030
SardHy Green Hydrogen	SardHy Green Hydrogen	IPCEI	green hydrogen integration	Oil refineries	Enel Green Power and Saras	Sardinia (Cagliari)	Close to market	Planned / Unknown
South Italy Green Hydrogen	South Italy Green Hydrogen	IPCEI	green hydrogen integration	Oil refineries	ENI (biorefinery)	Gela (Sicily) & Taranto	Close to market	Planned / Unknown

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union.
You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
- at the following standard number: +32 22999696,
- via the following form: european-union.europa.eu/contact-eu/write-us_en.

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

EU open data

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

This report maps demonstrators in energy-intensive industries, that develop technologies towards climate neutrality and have been financed by EU instruments (mostly Horizon Europe, Horizon 2020 and the Innovation Fund) or individual EU countries through Important Projects of Common European Interests.

These innovative technologies are in the fields of electrification, green hydrogen integration, carbon capture utilisation and storage, circularity and energy efficiency, and have been demonstrated in plants in the chemicals, cement, steel, glass, paper, ceramics industries or in oil refineries around Europe.

The mapped demonstrators need follow-up investment to bring these clean technologies to market by 2030, to enable climate neutrality of energy-intensive industries by 2050.

Research and Innovation policy

Publications Office
of the European Union