European Commission

ANNUAL KNOWLEDGE SHARING REPORT OF THE INNOVATION FUND

DE-RISKING INNOVATIVE LOW-CARBON TECHNOLOGIES

CINEA

Luxembourg: Publications Office of the European Union, 2024

PDF	ISBN 978-92-9405-081-6	doi:10.2926/895296	HZ-09-24-022-EN-N
Print	ISBN 978-92-9405-075-5	doi:10.2926/432617	HZ-09-24-022-EN-C
EPUB	ISBN 978-92-9405-041-0	doi:10.2926/861952	HZ-09-24-022-EN-E
HTML	ISBN 978-92-9405-052-6	doi:10.2926/38164	HZ-09-24-022-EN-Q

ANNUAL KNOWLEDGE SHARING REPORT OF THE INNOVATION FUND

DE-RISKING INNOVATIVE LOW-CARBON TECHNOLOGIES

MAIN AUTHORS:

Przadka, A., Sales Agut, C., Bravo, B., Grosjean, M., Iglesias, L., Timofte, C., Auboeck, A., Iavorenciuc, C., Miretti, U., Ettorre, F., Aleman, M., Caroli, G. and Ziogou, C.

July 2024

ABSTRACT

The Innovation Fund (IF), funded with revenues from the EU Emissions Trading System, is one of the world's largest funding programmes supporting the deployment of innovative net-zero and low-carbon technologies and knowledge sharing is an essential part of it. The objective of this report is to share knowledge gathered from the IF portfolio of projects that can help other projects looking to deploy innovative low-carbon technologies and minimise risks associated with scaling up. By the end of 2023, the IF project portfolio included 104 ongoing projects in the areas of energy-intensive industries, hydrogen, industrial carbon management, renewable energy or energy storage, with the committed EU contribution amounting to EUR 6.5 billion. By the end of 2023, 19 IF projects reached financial close, and four projects successfully entered into operation. Given their complexity in terms of size, technical ambition and reliance on external market and regulatory developments, IF projects encounter multiple challenges. This report sheds light on challenges related to difficult market conditions, securing finance and offtake agreements, regulatory bottlenecks, including on permit-granting procedures and technical constraints. The report provides insights into how IF projects apply different strategies to overcome these challenges and mitigate the corresponding risks. For example, delays caused by supply chain disruptions, higher capital expenditures or higher cost of capital are mitigated by ensuring sufficient contingencies in terms of project timing and budget, a clear governance structure and close monitoring.

CONTENTS

1. KEY MESSAGES

By the end of 2023, 19 Innovation Fund (IF) projects reached financial close (FC), and four projects successfully entered into operation. IF projects encounter multiple challenges due to their inherent high-risk profile, complexity in terms of size, technical ambition and their reliance on external market and regulatory developments.

- Challenging **market conditions**, stemming from geopolitical and economic crises, such as COVID-19 and the military aggression in Ukraine, have cascaded down on projects, leading to direct and indirect consequences: from delays caused by supply chain disruptions to higher capital expenditures and higher cost of capital. Contingencies in terms of project timing and budget, a clear governance structure (with clear responsibilities between parties and well-defined anticipative planning) and close monitoring constituted successful mitigation strategies.
- **Regulatory bottlenecks and challenges with permitting** have particularly affected projects operating in emerging and/or fast-growing sectors such as renewable hydrogen, renewable energy and energy storage. Projects mitigated these risks by initiating the permitting process in advance and engaging in a continuous dialogue with the relevant authorities.
- Some projects have experienced **technical constraints**, such as delays in the project preparatory phase and/or during construction. These mainly resulted from the high complexity of some projects, or their deployment in new locations or countries with limited experience with the envisaged technological solution. Simplifying processes and optimising the technical design helped overcome these constraints.
- The report finds that **securing finance** is a noticeable challenge for small-scale companies or newly created special purpose vehicles (SPVs). To secure funding for their projects, beneficiaries engaged in discussions with possible funders at an early stage. In addition, projects shareholders provided the necessary support (such as additional equity or guarantees) to facilitate the funding of the projects.

Projects in energy-intensive industries

- Energy-intensive industries (EIIs) projects share the same challenges as other IF projects, such as changed market conditions and **delays or disruptions in the supply chain**, or issues related to the regulatory framework and permitting. In addition, projects with a high electricity demand may experience issues in **securing grid connection and adequate grid capacity**, particularly those pursuing renewable hydrogen production and use, or electrification. To overcome this obstacle, some projects enter into close collaboration and negotiations with transmission system operators and distribution system operators from the inception of the project.
- Remaining competitive in the markets for new green products is also challenging for projects in the EIIs cluster. For example, the **high production costs** of projects developing green products, such as synthetic fuels, result in **difficulties in securing offtake agreements** under current market conditions. To overcome this issue, certain projects adopted a proactive strategy by engaging potential offtakers in project financing. They secured volume contracts from the early

stages of the project and established a diverse offtakers portfolio. Other projects redesigned technical aspects to reduce costs. For biofuels projects, revisions of national incentive schemes have directly impacted the business case of biofuels offtakers. Consequently, lead producers had to explore alternative applications of the product to capitalise on different markets offering more attractive incentives.

Projects with a hydrogen component

- The implementation of the renewable energy directive (RED) ([1]) is demanding as it is not easy to **align renewable electricity supply with hydrogen production** while fulfilling commitments to hydrogen offtakers and ensuring enough return on the investments. **Securing offtakers** also poses challenges, primarily due to existing infrastructure constraints. Some offtakers see RED targets for transport and industrial sectors not ambitious enough and they postpone paying the premium cost of the renewable hydrogen. Additionally, obtaining permits for a new technology that **lacks established EU standards** could result in long and complex validation procedures. These complexities, inherent to an emerging market, require careful planning with sufficient timing contingencies.
- Findings from the report indicate that successful hydrogen projects require robust project frameworks. This involves proactive and early identification of potential project risks, such as **technological, operational, financial and contract performance risks**. Implementing **effective risk mitigation strategies** is also essential. These strategies may include integrated projects involving renewable electricity suppliers and hydrogen offtakers, as well as partnerships and collaboration agreements with technology providers.
- Existing challenges underscore the importance of **simplifying permitting processes, extending the assistance to low-carbon and renewable hydrogen producers**, and fostering the exchange of technological solutions and project experiences.

Projects with a carbon capture and storage component

- For the projects dependent on external CO_2 storage services beyond their project boundaries, a primary concern lies in **the scarcity of CO_2 storage sites** available on the market within their relevant time frames. The imbalance between storage demand for planned capture projects and the availability of operational storage capacity significantly hampers the market's development and increases uncertainty related to storage costs. For carbon capture and storage (CCS) projects, **risk-sharing and risk-management mechanisms** must be addressed across a value-chain consisting of different industrial players. Experience gained from IF projects reveals an urgent need for harmonised **CO_2 standards** for transport and injection infrastructure given the disperse and different nature of emitters, differences in capture technologies, CO_2 purities and options for transport.

([1]) Directive – EU – 2023/2413 – EN – renewable energy directive – EUR-Lex: https://europa.eu/!tnv7RM.

- Projects that develop CO_2 storage sites within their project boundaries face challenges in **applying the CCS directive** ([2]) **provisions, and in addressing permitting needs** for CO_2 storage sites in a timely manner, as this is also a first-of-a-kind activity for managing authorities and prospective CO_2 storage sites operators. Clarity and guidance are needed for relevant authorities and project promoters to overcome regulatory barriers.
- Finally, projects generating net carbon removals face difficulties in **monetising the generated negative emissions**. Currently, investment decisions for this type of operations mainly rely on state subsidies or voluntary carbon markets. An agreement at political level on an **EU-wide voluntary framework for the certification of high-quality carbon removals** represents a significant advancement in the business case of such projects.

Projects with a renewable energy generation component

- Several projects encounter challenges in **ensuring offtake contracts**. Projects usually mitigate this risk by prioritising early dialogue with potential offtakers. Additionally, they leverage the assistance of specialised intermediaries (e.g. associations or network managers) and establish binding agreements and/or long-term contracts.
- Many projects also face **regulatory and permitting constraints**. Risk-management strategies feature setting careful timelines for project planning, early engagement with permitting authorities and being prepared to address permitting challenges, especially for the innovative elements of the project concept, where permitting requirements are not established.

Projects with an energy storage component

- Insights derived from energy storage projects indicate **regulatory and permitting challenges**. To overcome some of these obstacles, bi-directional electric vehicle (EV) charger deployment projects have strategically employed behind the meter (BTM) optimisation strategies for fleet charging schedules. This approach has facilitated the effective regulation of the contractual relationship between the supplier and the independent aggregator.
- Projects faced challenges in **establishing viable business models** for deploying energy storage systems (including thermal storage in district heating and vehicle to grid (V2G) stations deployment), as well as second-hand batteries repurposing and end-of-life battery recycling projects. To address these challenges, risk mitigation strategies were implemented, such as binding agreements with offtakers, adopting SPV ownership models and diversifying their funding sources through a mix of equity, debt and EU grants. In addition, projects such as end-of-life battery recycling and V2G implementation actions fostered strong partnerships across the value chain, facilitating technological development and harmonisation of product specifications. Heating-as-a-service projects incorporated additional revenue streams through additional revenue streams from using heat pump activation and deactivation to support grid stability.

([2]) Directive – 2009/31 – EN – EUR-Lex: https://europa.eu/!FvjFvN.

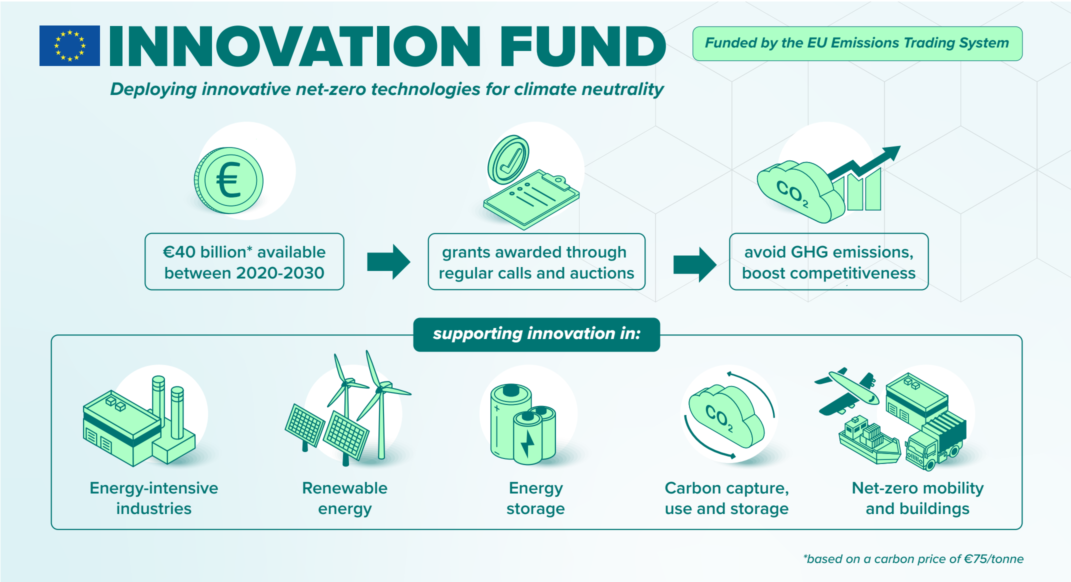
- **Supply chain disruptions and increased demand have caused price increases** in materials and semiconductors, **impacting the costs of electrical equipment**. In response, projects have strategically adjusted their initial plans by modifying transformer capacity, resizing designs, integrating a mix of new and second-life batteries or exploring the transition from nickel manganese cobalt to lithium iron phosphate battery systems. Projects have adopted proactive measures such as advance procurement planning, local sourcing, contingency planning and maintaining a strategic stock of critical items. They have also prioritised staying informed about market dynamics, leveraging parent companies' strength and implementing rigorous risk assessment strategies.

Many of the **challenges explained above require structured cooperation between public and private entities either at EU or at Member State level** to ensure that regulatory and market prerequisites for projects development are in place as soon as possible, in view of securing investment decisions. Fostering the exchange of technological solutions and project experiences will help in avoiding the costly repetition of inefficient approaches. Knowledge sharing and policy feedback are important elements for speeding up deployment of innovative low-carbon technologies.

2. INTRODUCTION

The Innovation Fund, financed with revenues from the EU Emissions Trading System (EU ETS) is one of the world's largest funding programmes supporting the deployment of innovative net-zero and low-carbon technologies.

Figure 1. The Innovation Fund in a nutshell.



Endowed with around 530 million EU ETS allowances until 2030, the IF supports projects focusing on:

- innovative low-carbon technologies and processes in energy-intensive industries (EIIs), including products that can substitute carbon-intensive ones;
- carbon capture and utilisation (CCU);
- construction and operation of carbon capture and storage (CCS) facilities;
- innovative renewable energy generation;
- energy storage;
- new sectors following the revision of the EU ETS directive (3): net-zero mobility (maritime, aviation, road transport) and buildings.

The IF aims to finance a project pipeline composed of a wide range of innovative technologies in all eligible sectors and EU/EEA countries (Figure 1).

Knowledge sharing is an essential part of the IF programme. The objective of knowledge sharing, and of this report, is to enhance market penetration and support the replication of the clean technologies or solutions funded by the programme, reducing their risks. Therefore, IF projects actively share the knowledge gained, supporting commercial scaling-up and accelerating both the deployment and the commercialisation of the technologies. Projects are required to share the acquired knowledge pursuant to Article 10a of the EU ETS directive. Knowledge sharing requirements are incorporated into grant agreements, requiring (4) beneficiaries to share the relevant knowledge acquired during the project's implementation with the European Commission.

(3) EU ETS Directive – 2023/959 – EN – EUR-Lex: https://europa.eu/!kxtCVJ.

(4) See Innovation Fund Model Grant Agreement: https://europa.eu/!FmWWjr.

3. METHODOLOGY

The data and project information presented in this report reflect the status on 31 December 2023.

Insights on project challenges and mitigation measures presented in this report are derived from knowledge sharing requirements of IF projects and thematic knowledge sharing workshops, which are discussed further in this section.

Sensitive project information has been aggregated and anonymised to protect confidential project data and to avoid reverse engineering. This report does not include information that fails to meet the minimum anonymisation and no-reverse-engineering requirements, which may occur when there is an insufficient number of projects of the same type. Public data collected in the framework of knowledge sharing activities, and other publicly available material are presented in a non-anonymised way.

Due to the wide spectrum of technologies covered within the IF portfolio, points in Section 5 structure information around five thematic clusters:

- energy-intensive industries ([5]), including carbon utilisation, biofuels and biorefineries;
- hydrogen, including manufacturing of components for hydrogen production and utilisation;
- carbon capture and storage;
- renewable energy generation, including manufacturing of components for renewable energy production; and
- energy storage, including manufacturing of components for energy storage.

This structure enables the presentation of cohesive, aggregated and anonymised knowledge accumulated to date, outlining key challenges and lessons learned from the project portfolio and respective thematic clusters.

Cross-cutting projects covering aspects of two clusters are analysed in both clusters. For example, a project producing hydrogen from water electrolysis and utilising it in a chemical reaction with captured carbon is referred to in both hydrogen and EIIs clusters. The attribution of projects per cluster, respective EU funding, greenhouse gas (GHG) emission savings and projects' main location are presented in the Annex.

([5]) The energy-intensive industries (EIIs) in the scope of the Innovation Fund programme follow Annex I of the EU ETS directive (https://europa.eu/!kxtCVJ), including sectors such as refineries, iron and steel, non-ferrous metals, cement and lime, glass, ceramics and construction materials, pulp and paper, and chemicals.

IF projects have two key project milestones, FC (6) and entry into operation (EIO) (7). These milestones are only considered as achieved once they have been validated by the granting authority (8). Therefore, projects without validated FC and EIO milestones are categorised as projects that have not achieved them yet for the purposes of this report.

The quantitative details included in this document are provided for information purposes only, based on current expectations and assumptions, and inherently subject to significant uncertainties and changes in circumstances. Please be advised that these assumptions should not be regarded as firm predictions, and actual results may differ. The expected GHG savings presented in this report are based on the relevant GHG methodology applicable to the projects at the time of their application to the IF. The ramp-up periods to achieve full-capacity production are omitted in the calculations for simplification purposes.

The early stage of project portfolio does not provide sufficient level of data to elaborate further on potential scalability effects and operational aspects of ongoing projects.

The Commission (Directorate-General for Climate Action) and CINEA regularly organise knowledge sharing workshops, addressing challenges and opportunities of the innovative low-carbon technologies. The meeting summaries, presentations and background documents of the past events on CCS, hydrogen and energy storage are available on CINEA's website (9). Findings of these meetings are integrated into this report. Knowledge sharing workshops dedicated to renewable energy and decarbonisation pathways in energy-intensive industries are planned to take place in 2024 and in the years that follow. Findings of these meetings, along with further knowledge gained from the growing portfolio, will be integrated into the next editions of this report.

(6) 'Financial close' is the moment in the project development cycle when all the project and financing agreements have been signed and all the required conditions contained in them have been met.

(7) 'Entry into operation' is the moment in the project development cycle when all elements and systems required for operation of the project have been tested and activities resulting in effective avoidance of greenhouse gas emissions have commenced.

(8) The granting authority is the European Climate, Infrastructure and Environment Executive Agency (CINEA) https://cinea.ec.europa.eu/index_en.

(9) CCS closed-door knowledge sharing workshops: 28 November 2023, Knowledge sharing workshop on CCS – Realising opportunities along the value chain (summary: https://europa.eu/!7vHGdD, and slide packs: https://europa.eu/!pJ9Qc7, https://europa.eu/!7cwRnB, https://europa.eu/!tNvyPB and https://europa.eu/!4kpDrb);
10 October 2023, Knowledge sharing workshop on energy storage – Key takeaways and best practices to reach financial close (summary: https://europa.eu/!MptN38);
19 September 2023, Knowledge sharing workshop on hydrogen – Main challenges in reaching financial close and ways to tackle them (summary: https://europa.eu/!MptN38);
30 March 2023, The emerging EU CO_2 transport and storage market (summary: https://europa.eu/!RTwX4Y, slide pack: https://europa.eu/!DcQmpH, and project fiche: https://europa.eu/!gBMGHM);
15 September 2022, Main challenges in reaching financial close and ways to tackle them (summary: https://europa.eu/!KTBTvf and slide pack: https://europa.eu/!bYXv6j);
15 February 2022, Knowledge sharing workshop on CCS directive – Innovation Fund and projects of common interest (PCIs) (summary: https://europa.eu/!w9JK64).

4. INNOVATION FUND PROJECT PORTFOLIO

4.1. Portfolio overview

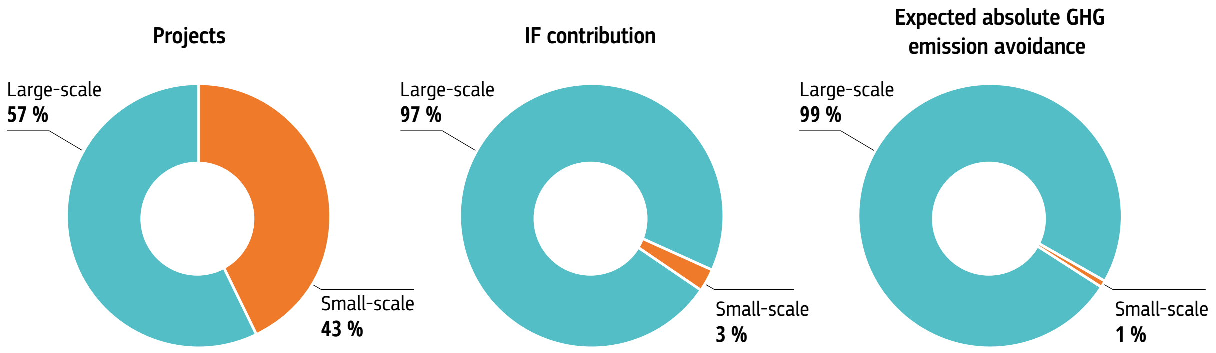
The IF opened its first call for proposals on 3 July 2020. Since then, six other calls have been launched. The IF portfolio consists of **104** projects, among which **45** are small-scale and **59** are large-scale [10]. The total committed IF contribution for these projects amounts to **EUR 6 469 666.52**.

Table 1 summarises the number of projects per type of call. Small-scale projects represent a 43 % share of the portfolio, but only account for 3 % of total IF funding.

Table 1. Portfolio overview by end of 2023.

Call year	Type of call	Number of projects	Funding (EUR)	CAPEX (EUR)
2020	large-scale call (LSC-2020)	7	1.1 billion	≈ 5 billion
	small-scale call (SSC-2020)	29	105 million	≈ 205 million
2021	large-scale call (LSC-2021)	16	1.8 billion	≈ 9 billion
	small-scale call (SSC-2021)	16	59 million	≈ 108 million
2022	large-scale call (LSC-2022)	36	3.3 billion	≈ 21.5 billion
	small-scale call (SSC-2022)	grant agreement preparation ongoing		
Total (excluding SSC-2022)		**104 projects**	**6.5 billion**	**35.8 billion**

Figure 2. Overview of portfolio – distribution of projects, IF contribution, and absolute GHG emission avoidance between large-scale and small-scale projects.



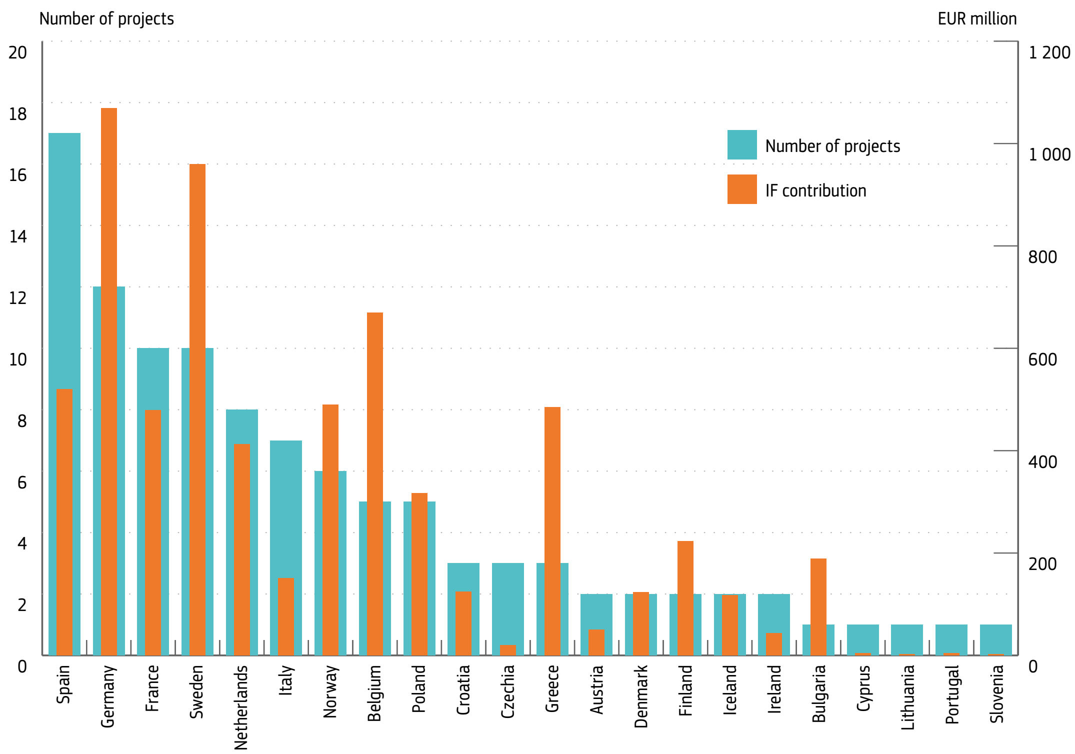
[10] In the 2020–2022 IF calls, a small-scale project means a project with a capital expenditure (CAPEX) between EUR 2.5 million and EUR 7.5 million, while a large-scale project (including large-scale pilot demonstration project) means a project with CAPEX above EUR 7.5 million.

The expected absolute GHG emissions avoidance of ongoing IF projects, calculated over 10 years of operation, sums up to 442 million tonnes of CO_2 equivalent ([11]), 99 % of which (432 million tonnes of CO_2 equivalent) stem from large-scale projects (Figure 2).

The expected investment volume (CAPEX) of the ongoing IF projects is around EUR 35.5 billion for large-scale projects and EUR 313 million for small-scale projects, which combined represents more than five times the IF funding committed.

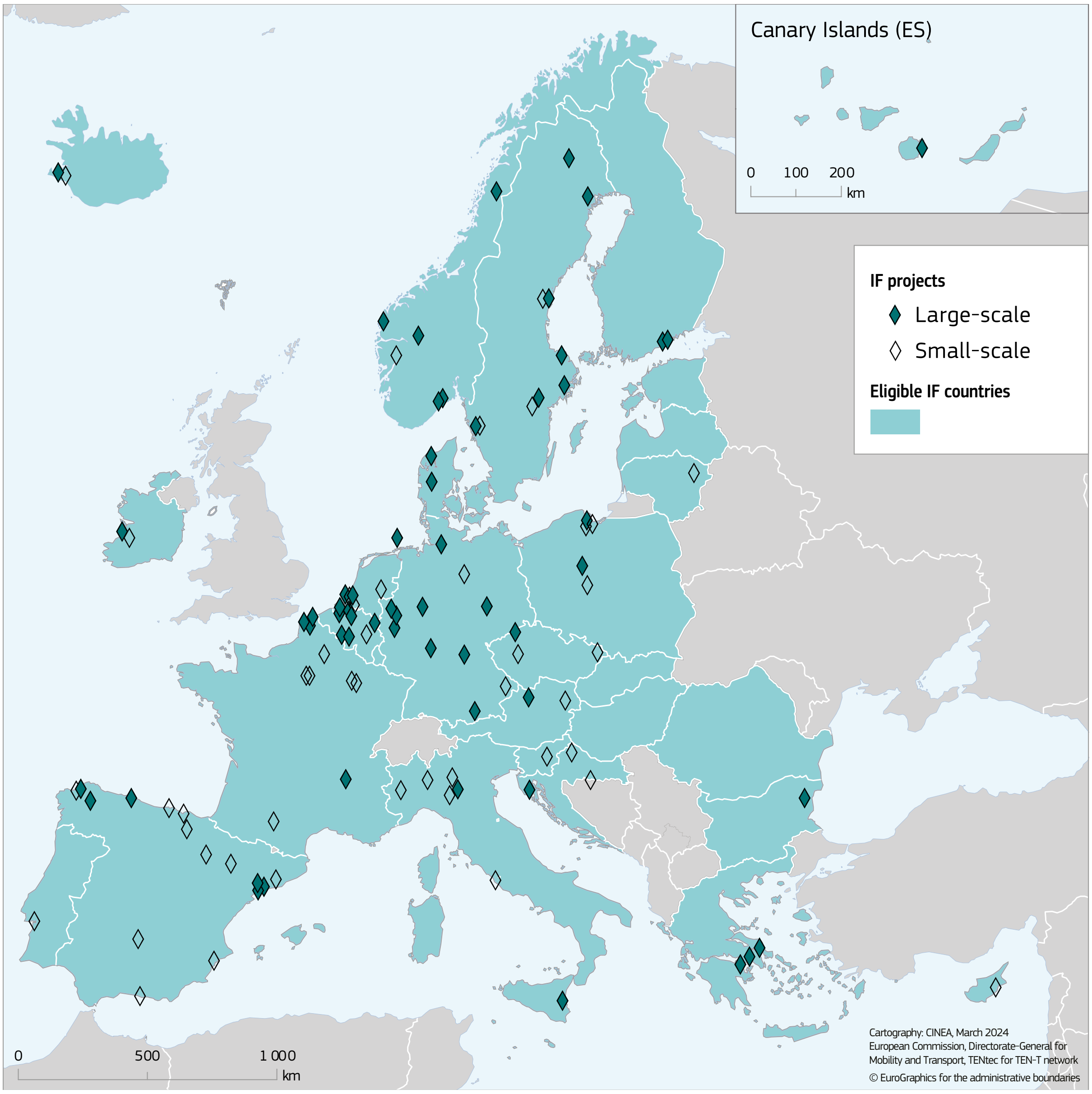
IF projects can be found in 22 countries, some of them in multiple locations. The most frequent locations for projects are Spain (17), Germany (12) and France (10) (Figure 3). Projects implemented in Germany, Sweden and Belgium benefit from the highest IF contribution overall. The geographical distribution of large and small-scale projects per main country of implementation is shown in Figure 4.

Figure 3. Distribution of projects and IF contribution per main country of implementation.



([11]) As per the applicable IF GHG emission avoidance calculation methodology.

Figure 4. Geographical distribution of the IF portfolio, with large-scale and small-scale projects per main country of implementation.



SYNERGIES WITH OTHER EUROPEAN UNION PROGRAMMES

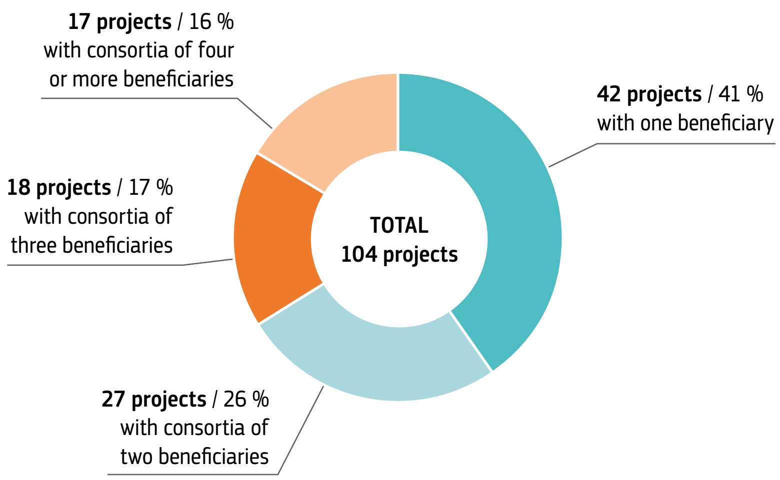
The current IF portfolio features eight projects which directly build upon results of previous EU-funded projects. These projects mainly benefited from EU research and innovation actions (RIA) grants received under the Horizon 2020 programme and the 7th framework programme. For example, the CO_2 geological storage technology deployed in the projects Coda Terminal and Silverstone was previously supported by four EU RIA grants from the Horizon 2020 programme. Project ANRAV benefited from four grants to develop technologies on carbon capture in the cement industry. In addition, several IF projects benefit from synergies created with other EU-funded programmes, such as LIFE ([12]), CEF ([13]), EMFAF ([14]), the EIC Accelerator ([15]) (part of Horizon 2020 and Horizon Europe programmes), Interreg ([16]) and REACT-EU ([17]).

INNOVATION FUND BENEFICIARIES

The 104 ongoing IF projects are implemented by 213 participants ([18]): 202 privately owned, for-profit entities, five public entities, four research organisations, one higher education establishment and one non-governmental organisation (NGO).

Many of the IF projects are mono-beneficiary or are managed by small consortia. Figure 5 captures the distribution of the IF portfolio per consortia size.

Figure 5. IF portfolio per consortia size.



([12]) LIFE Programme: https://europa.eu/!96n39t.

([13]) Connecting Europe Facility: https://europa.eu/!bNgcwB.

([14]) European Maritime, Fisheries and Aquaculture Fund: https://europa.eu/!cYGGg4.

([15]) EIC Accelerator: https://europa.eu/!Hb36mw.

([16]) Interreg: https://europa.eu/!x768Mm.

([17]) Recovery assistance for cohesion and the territories of Europe (REACT-EU): https://europa.eu/!4GMp4C.

([18]) Participants include beneficiaries, associated partners and linked third parties. For more information regarding the roles and attributions in the IF grants please consult Article 7 of the Model Grant Agreement (https://europa.eu/!HDdGkM).

4.2. Financial close and entry into operation status and analysis

STATUS

As the IF aims to support cleantech solutions that can be deployed rapidly, projects must reach the first mandatory milestone, FC, within a maximum of 4 years from the grant signature. This period of time reflects the market practice-based time that is required for the preparation, construction and operation of the complex and innovative projects financed under the IF.

Out of 104 projects in the IF portfolio, 19 projects reached FC: 17 small-scale projects (14 selected in SSC-2020 and three in SSC-2021) and two large-scale projects (one selected in LSC-2020 and one selected in LSC-2021), as shown in Figure 6.

Out of the 19 projects that reached FC, four small-scale projects have also successfully entered into operation.

Figure 6. Status of the IF portfolio according to the project implementation status.

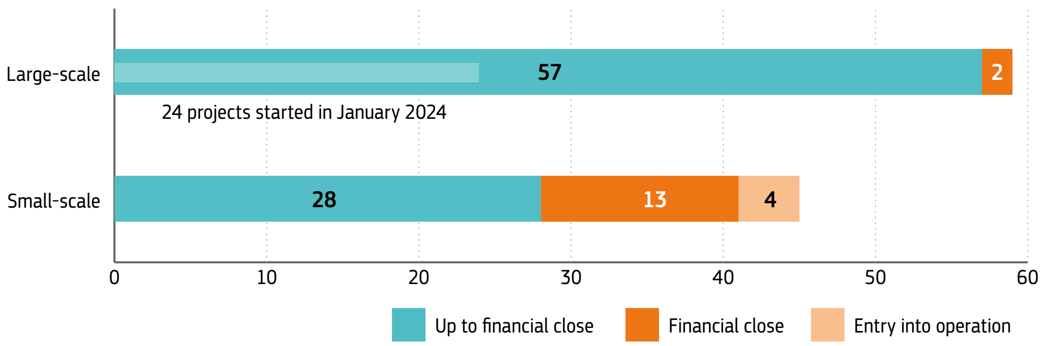


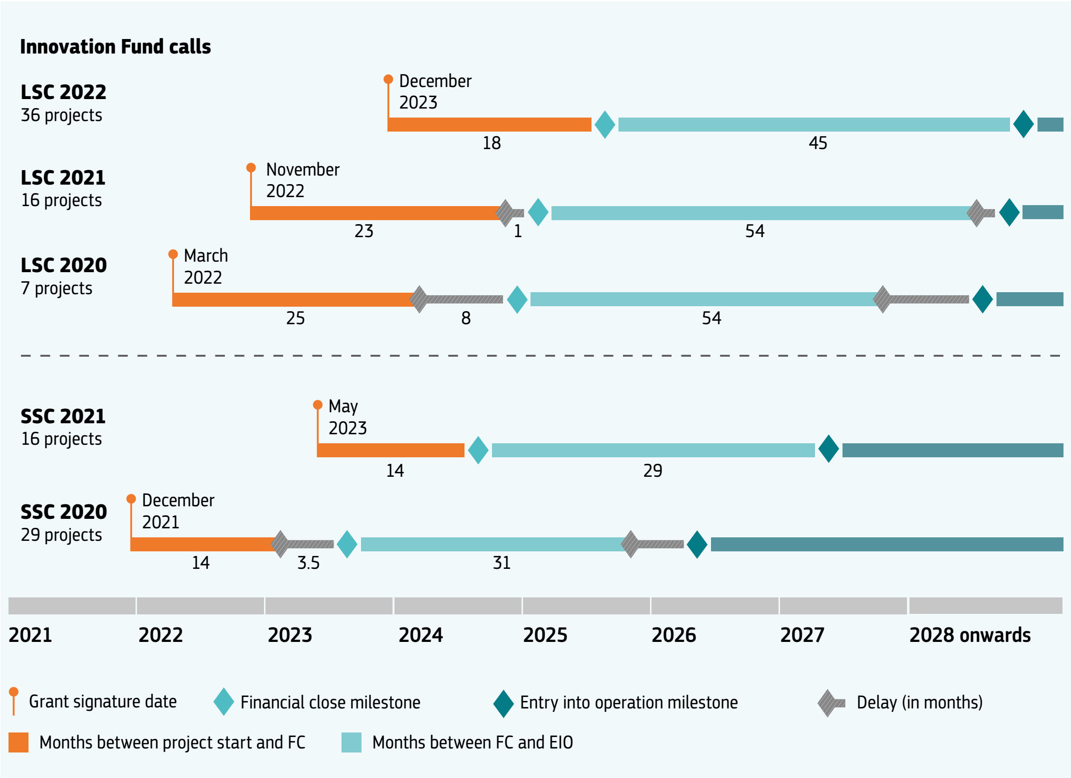
Figure 7 presents the average time to reach FC and EIO per call and the average delay in reaching the respective milestone [19].

For small-scale projects, the average time to reach the key milestones remains similar across the calls (14 months from the grant start to FC, and approximately 30 months between FC and EIO, excluding delays). Large-scale projects require more time to reach FC and much longer periods between FC and EIO due to their substantial size and complexity, during both the investment process and the construction phase. At the same time, it appears that projects supported under the last large-scale call (LSC-2022) expect a considerably shorter time to reach FC and EIO compared to previous calls (LSC-2020 and LSC-2021). It can be argued that some of these projects have been submitted to multiple IF calls, thereby attaining a higher level of maturity over time. Furthermore, for some of these projects, the starting date was the end of 2023, thus no delays have been reported yet. The average period per call to reach FC is still well below the maximum period of 48 months, on average 25 months for large-scale projects and 15.8 months for small-scale projects.

[19] Only confirmed delays validated through signed amendments to the grant agreement are taken into account.

Generally, delays in reaching FC result in delays in the EIO date. Some projects compensate for delays in FC by adjusting the construction timeline to meet the planned EIO date.

Figure 7. Overview of the portfolio average time to reach FC and EIO milestones.



ANALYSIS

Projects face numerous challenges to achieve FC, and they are often confronted with several of them simultaneously. The most common challenges are listed in descending order, along with the most effective mitigation measures, discussed in more detail under points 5.1 to 5.5 of this report:

(i) delays in equipment supply and rise in material/energy costs;

(ii) securing offtake contracts;

(iii) regulatory challenges and delays in obtaining permits;

(iv) facing unexpected technical constraints;

(v) changes to the organisational setup.

(i) Delays in equipment supply and rise in material/energy costs

Supply chain disruptions, labour shortages and longer lead times for the delivery either of raw materials or equipment posed significant challenges to the timely implementation of projects.

Successful mitigation strategies employed by IF projects include anticipating orders and coordinating with suppliers, and diversifying the supplier portfolio. In some cases, projects renegotiated delivery schedules with their offtakers to accommodate longer delivery times.

Furthermore, surging prices for raw materials, components, energy and the transportation of goods prompted modifications to the initial project budgets. For instance, within projects with an energy storage component, increased prices of materials like copper, aluminium, steel and semiconductors, significantly impacted the cost of electrical equipment. For example, developers of offshore wind farms have encountered higher-than-budgeted wind turbine installation costs and some hydrogen projects are faced with higher electrolyser costs. These challenges were mostly addressed by increasing planned budgets, asking shareholders for additional contribution and renegotiating contracts with customers. Moreover, a clear governance among project parties combined with the close monitoring of the progress were effective measures in all clusters and for all industrial sectors. Governance arrangements would include a clear decision-making process and accountability framework.

Some projects aimed at manufacturing components for energy storage or components for renewable energy production face heterogeneous supply chains. Typically, in a heterogeneous supply chain every supplier is unique and there may be variations in the types of products, production processes, technologies used, geographical locations and regulatory requirements. Managing a heterogeneous supply chain often involves addressing complexities associated with coordinating and integrating these diverse elements to ensure smooth operations, optimise efficiency and meet customer demands effectively. Heterogeneous supply chains, coupled with limited feedstock volumes (e.g. second-hand and end-of-life batteries) and the absence of pricing for raw (European) recycled materials, have favoured projects with larger orders. This placed smaller companies at a disadvantage. To tackle these challenges, projects have adopted a proactive approach, prioritising advanced procurement planning, local sourcing, contingency planning and maintaining strategic stocks of critical items.

Projects in other clusters, such as EIIs, implemented rigorous risk assessment strategies, stayed constantly informed about market dynamics, relied on support from a parent company or group and proactively participated in the promotion of new processes and their own products through demonstrators and prototypes.

For some projects, on the other hand, the increase in energy prices and tight supply of imported fossil fuels created an opportunity to move business away from natural gas. For example, in the pulp and paper industry, this is possible due to the nearby availability of wood residues.

Figure 8.
Project AGRIVOLTAIC CANOPY – building a 5-metre-high agrivoltaic canopy. The canopy is designed to enhance agricultural production thanks to the intelligent irrigation and rotation shading systems.

(ii) Securing contracts with offtakers

Difficulties in securing offtake agreements with favourable terms is one of the most prominent factors contributing to delays in reaching FC. This challenge is partly attributed to the innovative nature of the projects supported by the IF, as they target new markets and/or develop new products or solutions.

Some projects within the hydrogen and EII clusters encountered challenges in customer identification. This can be attributed to low product demand or resistance towards paying a green premium. Additionally, some faced significant regulatory risks and encountered obstacles in risk-sharing and the negotiation of commercially viable terms with offtakers. In the same vein, projects facing increased CAPEX and/or OPEX were under pressure to renegotiate offtake agreements with more favourable terms to cover the increased cost and maintain the expected profitability.

Projects assessed the risks of relying on multiple offtakers, recognising the potential impact on financial viability if these offtakers decrease their planned purchases. These considerations were particularly salient in heat-as-a-service-related projects, where revenue primarily comes from selling heat through customised agreements. Early engagement with potential offtakers and the adoption of a flexible business plan were identified as effective strategies to improve projects' chances of success in securing agreements. These measures included the ability to accept less favourable contract terms.

Figure 9.
Project SKFOAAS – processing plant for reconditioning industrial lubricants using a double separation technology to remove all contaminants from used oils and return it to a clean, usable and high-grade product, thereby avoiding the disposal of the used oil.

(iii) Regulatory challenges and delays in obtaining permits

Nine projects reported challenges in obtaining the relevant permits, resulting in requests for extension of the contractual timeline to FC. In addition, four projects experienced delays attributed to the limited experience of permitting authorities in handling the proposed innovative solutions, or to the necessity to develop new types of permit procedures, such as the end-of-waste permits needed to valorise previously unexploited waste streams. In addition, projects reported shortages in permitting authorities' personnel, leading to slower processing of permit applications and therefore granting delays. Finally, two projects admittedly underestimated the time and effort needed to acquire the permits and failed to proactively engage with the relevant public authorities, leading to a delay in reaching FC. A primary insight from project beneficiaries emphasised the need to actively engage with regional authorities to streamline administrative procedures for obtaining operating and environmental permits.

Projects implementing first-of-a-kind industrial technologies typically operate in a more unstable regulatory framework which is still under development. For example, projects promoting the integration of energy storage solutions faced unclear or incomplete market rules. To overcome these challenges, consulting firms with expertise in issues related to the siting and operation of battery charging and discharging stations played a crucial role in obtaining the required permits.

Obtaining the necessary construction permits from local and national authorities in a timely manner represented an obstacle for some projects. For example, renewable hydrogen projects reported difficulties in securing renewable electricity due to long permitting processes for developers of renewable energy projects, and due to regional differences in permitting procedures. In addition, extra studies were needed due to the lack of EU standards for the hydrogen production plant, leading to environmental permit delays. Based on the insights gained from the IF projects, initiating the permitting process at an early stage and establishing an ongoing communication channel with the relevant authorities have been beneficial.

(iv) Technical constraints

The number of projects affected by technical challenges is not significant. Some projects have found simpler processes or have optimised the initial design, while maintaining their objectives, while others needed to react to enhanced risks such as ground stability or explosion risks. Technical issues are likely to gain importance as more projects reach FC and start construction and operation. Sufficient buffer time to overcome such constraints should be considered in each project.

(v) Changes to organisational set-up

Changes to the organisational set-up can have important implications, especially if a key project partner such as a proprietary technology holder or a financier decides to leave a consortium, as this may undermine viability of the business plan. Consortia successfully mitigated this risk by replacing the technology provider with another offering similar solutions. To date, there were only a few isolated cases where a key partner could not be replaced because of its unique technology or skills, thus putting the whole project in jeopardy.

Figure 10.
Project EB UV – the deployment of a first-of-a-kind full-scale process for curing paint on steel substrates (to avoid the presence of moisture) in Contrisson (France).

IMPACT OF CHALLENGES ON FINANCING AND FINANCIAL CLOSE

Projects were typically confronted with a combination of challenges which could potentially impact the project's ability to secure the required financing. Insights from projects have shown that failure to secure agreements with anticipated suppliers for essential equipment may require negotiations with alternative suppliers and a revisiting of the project's financing needs.

Some small companies or SPVs struggle to secure finance, while projects with shareholders willing to provide the necessary guarantees to ensure the funding are more likely to succeed.

The majority of the ongoing IF projects are expected to be funded entirely using a combination of equity and IF grants. One of the reasons is that innovative projects are perceived risky by potential debt providers due to the lack of historical performance data and market standards allowing to price the risks for lenders. Another reason is the complexity of having to manage and coordinate multiple project funders in a timely manner. Consequently, achieving FC while having many funding sources may take longer.

Securing additional funding may be limited if more financing is needed than initially planned. Some projects may plan to get extra state aid support, but it may be reduced by state aid thresholds and might not be enough to meet the total funding needs. Therefore, based on the gained experience, it is recommendable to include a sufficient number of contingencies with adequate financial backing from project shareholders.

Amending the IF grant agreements to postpone the FC date may prove inadequate if project developers encounter issues with significant implications for the commercial and financial viability of their projects. These issues may not be addressed solely through further process optimisation, temporarily downsizing certain aspects of the project or entering into new commercial agreements with more favourable terms.

If no viable alternatives can be found, the ability of these projects to ultimately reach FC may be at risk. Projects may have their grant agreement terminated after it becomes clear that a solid plan to address the delays and to reach FC, within a foreseeable time horizon, cannot be achieved. This applies to only a few projects so far, that were unable to overcome substantial challenges within a foreseeable time frame (see point (v) 'Changes to organisational set-up'). However, this is a common aspect of investments in novel and risky technologies, especially during rapid market changes.

5. CHALLENGES AND KEY MESSAGES PER INNOVATION FUND CLUSTER

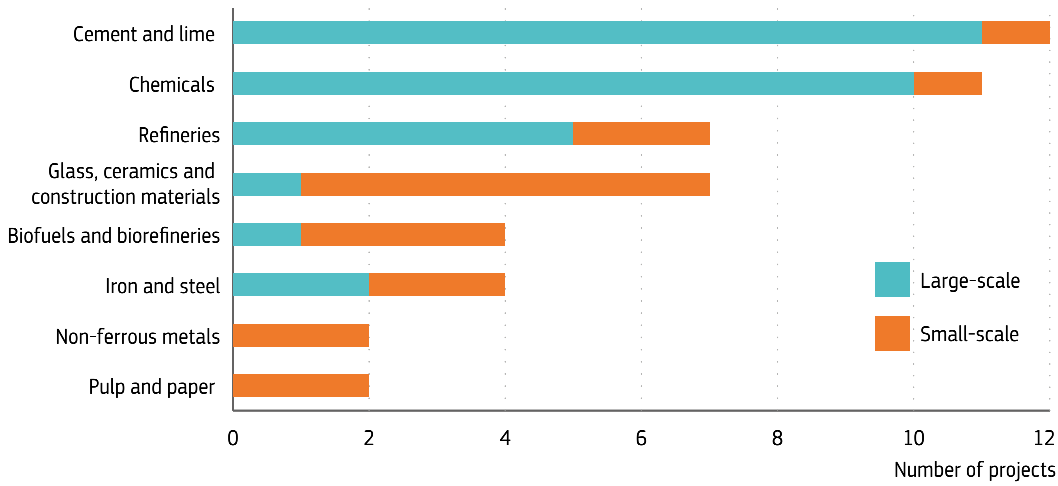
5.1. Energy-intensive industries

PROJECTS IN THE EIIs

The EIIs cluster covers 49 ongoing projects ([20]) with a total capital investment (CAPEX) of more than EUR 18 billion. The projects are located in 18 countries, one third of them being implemented in Sweden and Spain, with others concentrated in Belgium, France and Germany.

Within the EIIs cluster, the number of projects varies significantly across different industries (Figure 11). Industrial sectors, such as chemicals, refineries, cement and lime, and iron and steel, feature most of the large-scale projects, while pulp and paper, non-ferrous metals, biofuels and biorefineries, and glass, ceramics and construction materials are primarily or exclusively represented by small-scale ones.

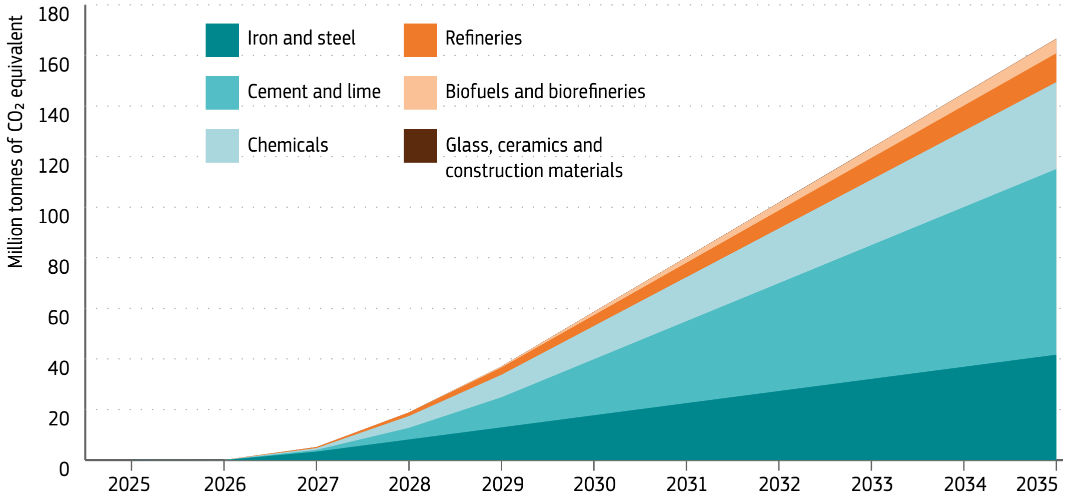
Figure 11. Number and types of projects in the EIIs cluster.



([20]) The EIIs projects that dedicate their core activities to CCS are analysed in more detail later in point 5.3. EIIs projects that produce renewable and low-carbon hydrogen and use it in their processes are considered in detail in point 5.2. Additionally, the EIIs cluster also includes projects related to biofuels and biorefineries.

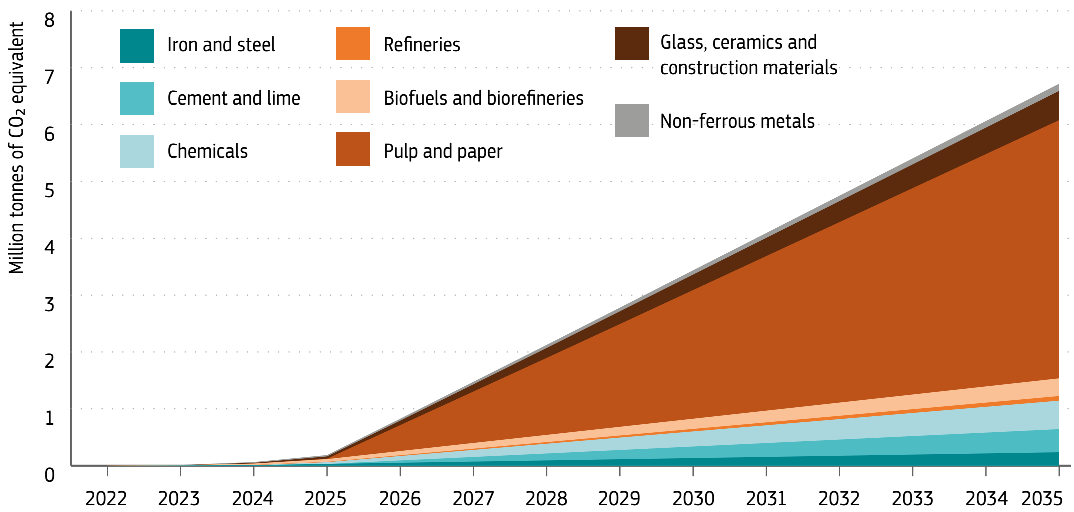
All large-scale projects in the EIIs cluster are expected to enter into operation between 2027 and 2029. The distribution of the EIIs portfolio between large-scale and small-scale projects has an impact on the expected GHG emission reductions per sector. Namely, large-scale projects in the cement and lime, iron and steel, and chemicals industrial sectors are expected to make a major contribution to the GHG emission avoidance in this cluster (Figure 12).

Figure 12. Expected cumulative GHG emission avoidance per sector of large-scale project in the Ells cluster.



Nearly all the EIIs small-scale projects plan to reach EIO by the end of 2026. Four small-scale EIIs projects successfully entered into operation between 2022 and 2023: AAL SEB (non-ferrous metals), EB-UV (iron and steel), SKFOAAS (refineries) and W4W (biofuels and biorefineries). Among EIIs small-scale projects, pulp and paper projects are expected to achieve the highest share of GHG emissions avoidance (Figure 13).

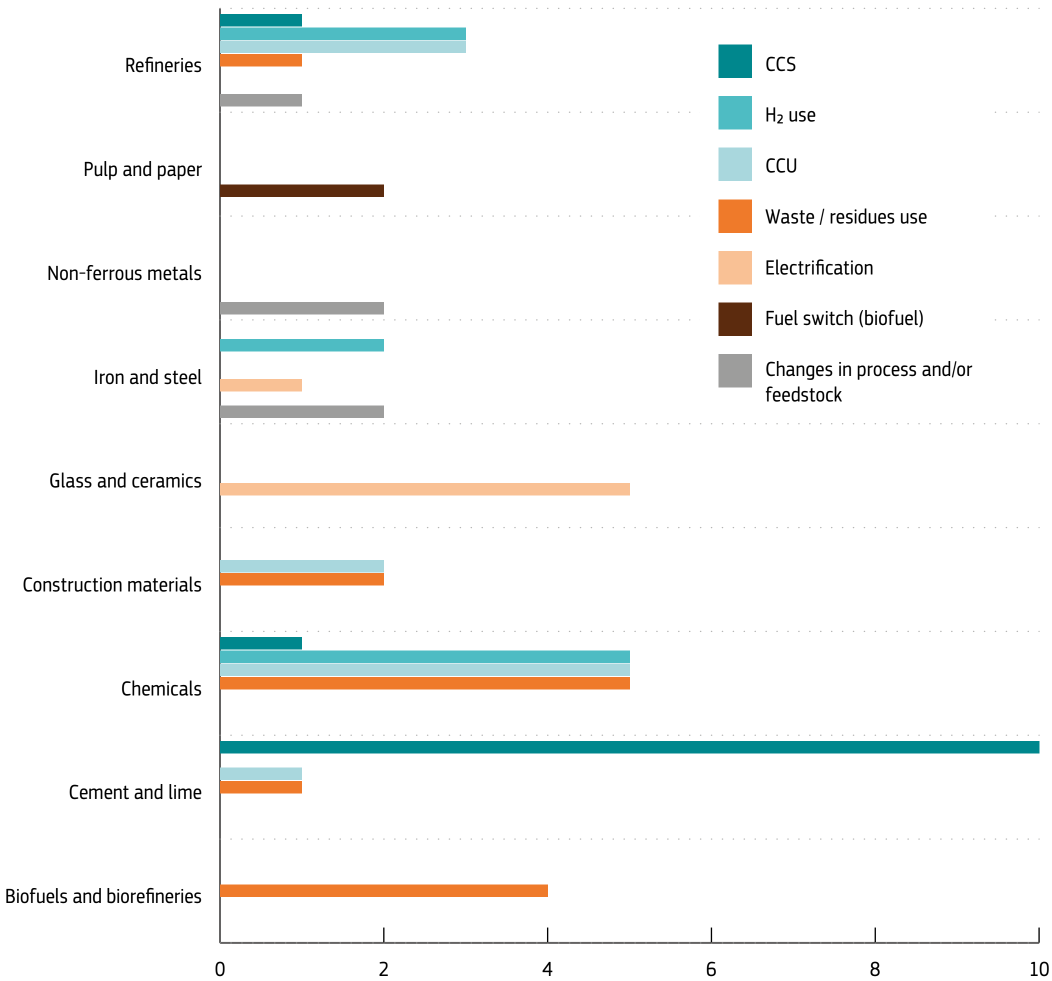
Figure 13. Expected cumulative GHG emission avoidance per sector of small-scale project in the Ells cluster.



EIIs DECARBONISATION PATHWAYS PER SECTOR

Decarbonisation pathways vary across industrial sectors. Nevertheless, some trends can already be identified (Figure 14).

Figure 14. The main decarbonisation pathways per industrial sector in the EIIs cluster.



Some industrial sectors prioritise a single decarbonisation pathway. For instance, projects in the cement and lime sector predominantly propose CCS solutions; biofuels and biorefineries projects focus on the use of waste and residues; projects in the glass industry consider exclusively electrification, while pulp and paper projects prioritise substituting fossil fuels with biofuels produced on-site.

Other sectors employ a combination of different decarbonisation pathways. Chemicals, refineries and construction materials projects extensively explore solutions based on CCU, waste/residue utilisation, or a combination thereof. The production and usage of renewable and low-carbon hydrogen, often combined with CCU, is a common feature of iron and steel, chemicals and refineries projects.

Alongside the decarbonisation pathways mentioned above, certain projects aim to reduce GHG by changing processes or the feedstock used. Examples of such approaches can be found in the refineries, iron and steel, cement and lime, and non-ferrous metals sectors.

EIIs PRODUCTS AND PROCESSES PER SECTOR

Figure 15.
Project W4W – cost-competitive and grid-compliant biomethane from landfill gas using the WAGABOX® technology implemented in one of the largest landfills in Spain.

BIOFUELS AND BIOREFINERIES

Projects in the biofuels and biorefineries sector can be classified into two main groups based on their feedstock and final products. Firstly, waste-to-gas projects propose converting biogas from bio-based waste, such as organic municipal and agri-food waste, into gaseous fuels like biomethane. Examples of such projects include the FirstBio2Shipping project, which aims to convert biogas from organic waste into bio-LNG for cleaner marine fuel, and W4W, which produces grid-compliant biomethane from landfill. Secondly, biomass-to-liquid projects (e.g., project BioOstrand) typically convert biomass, mainly forest residues, into liquid fuels like sustainable aviation fuel (SAF).

CEMENT AND LIME

The distribution of cement and lime projects in the IF portfolio reflects the sector's reliance on carbon capture, utilisation and storage solutions to mitigate process emissions, especially CO_2 emissions associated with the calcination of raw materials. Ten projects propose CCS and are considered in point 5.3. Other projects, such as C2B, focus on CCU, and Clyngas aims at the substitution of fossil fuels with waste-derived fuels.

CHEMICALS

Most of the projects in the chemical sector aim to produce green methanol (e.g. GREEN MEIGA and AIR) or green ammonia (e.g. GAP and GRAMLI) through renewable and low-carbon hydrogen production and CCU. Additionally, there is an increased emphasis on circularity, with some awarded grants supporting projects aiming to produce sustainable plastics through waste recycling (e.g. SC-HOOP).

CONSTRUCTION MATERIALS

Two small-scale projects have been granted in this field so far. Project CO_2ncrEAT uses by-products of stainless-steel production and CO_2 captured from a lime plant to produce carbon-negative precast materials. The second project, AGGREGACO$_2$, uses fly ash, slag and air pollution control residues to produce aggregates for the construction sector.

GLASS AND CERAMICS

Glass and ceramics IF projects focus only on glass production, targeting mostly container glass as a final product. An exception is the VOLTA project, which targets float glass production via an all-electric melting technology and oxy-gas combustion that are combined in an integrated furnace with up to 100 % cullet recycling, also envisaging the possibility of gas (hydrogen) blending in its future developments.

IRON AND STEEL

The main decarbonisation trend in the iron and steel projects involves transforming the ironmaking process by replacing coke-fuelled blast furnaces (BF) with direct reduced iron (DRI), using hydrogen as the primary reducing agent. This transition is complemented by the electrification of steelmaking, shifting from basic oxygen furnaces (BOF) to electric arc furnaces (EAF). Two large-scale projects illustrating this shift are the Hybrit demonstration and H_2GS project. Other projects target the decarbonisation of specific stages of production. For instance, the EB UV project replaces the traditional curing ovens in continuous coil coating lines with a new technology based on electron beam curing. The Helexio line project proposes a solution to manufacture 'ready to plug in' photovoltaic steel roofing panels.

NON-FERROUS METALS

The non-ferrous metal industry includes two projects focused on enhancing sustainability and efficiency. Project AAL SEB introduces a high-pressure electric boiler in an alumina refinery with the objective of reducing GHG through the integration of renewable energy sources. Project Green Foil is upgrading its process to enable the production of EV-battery grade aluminium foil.

PULP AND PAPER

The sector is represented in the IF portfolio by two small-scale projects. Both projects target fuel use, replacing natural gas with hardwood residues (project LK2BM) or with bio-syngas from wood wastes (project TFFFTP).

REFINERIES

In the refinery sector, the resulting products widely depend on the decarbonisation pathway and the intended use for the product. For example, the E-Fuel Pilot project uses captured CO_2 and renewable and low-carbon hydrogen to create Fischer-Tropsch waxes, which are then refined into sustainable aviation fuels (SAF). Other projects, like Triskelion, synthesise e-methanol from captured CO_2 and hydrogen for the transportation sector, while the Columbus project aims to produce e-methane for maritime use by combining captured CO_2 from a lime plant with renewable hydrogen generated through methanation.

CHALLENGES AND LESSONS LEARNED

The challenges faced by EIIs projects include **changes in the market conditions** and **delays or disruptions in the supply chain**, both issues related to the **regulatory framework and permitting** (see point 4.2).

In addition, for high electricity-demanding projects, **securing grid connection and adequate grid capacity** can also be challenging, particularly for projects pursuing renewable hydrogen production and use, or electrification. To overcome these challenges, some projects have established a **close collaboration and engaged in early negotiations** with the transmission system operator and distribution system operator from the inception of the project.

Remaining competitive in the markets for new green products poses concrete challenges to projects. For example, e-fuels and e-methane produced by integrating renewable energy sources, electrolysis-based hydrogen production and advanced chemical processes encounter challenges during the commercialisation stage. A major hurdle is their high production cost, attributed to the required advanced technologies and significant CAPEX investments. Consequently, projects encounter challenges in **securing offtake agreements** under current market conditions. Some projects mitigate this issue by **involving potential offtakers in the project financing, securing volume contracts from the project's early stages, and establishing a diverse offtakers' portfolio**. Others, to reduce costs while ensuring the validity of the initial objectives and targets, **re-design certain technical aspects of the project** (e.g. use of standard equipment instead of custom-made options).

A similar challenge is experienced by biofuel production projects due to **uncertainty in the final price of the product** in some Member States. Measures implemented at national level to incentivise the adoption of biofuels in specific market segments are undergoing revision in accordance with the transposition of the RED. **Recent amendments to these incentive schemes** in some Member States directly impact the business case of biofuels offtakers, leading to the need to look for mitigation measures. This may involve **seeking alternative applications of the product in a different market segment with more attractive incentives**.

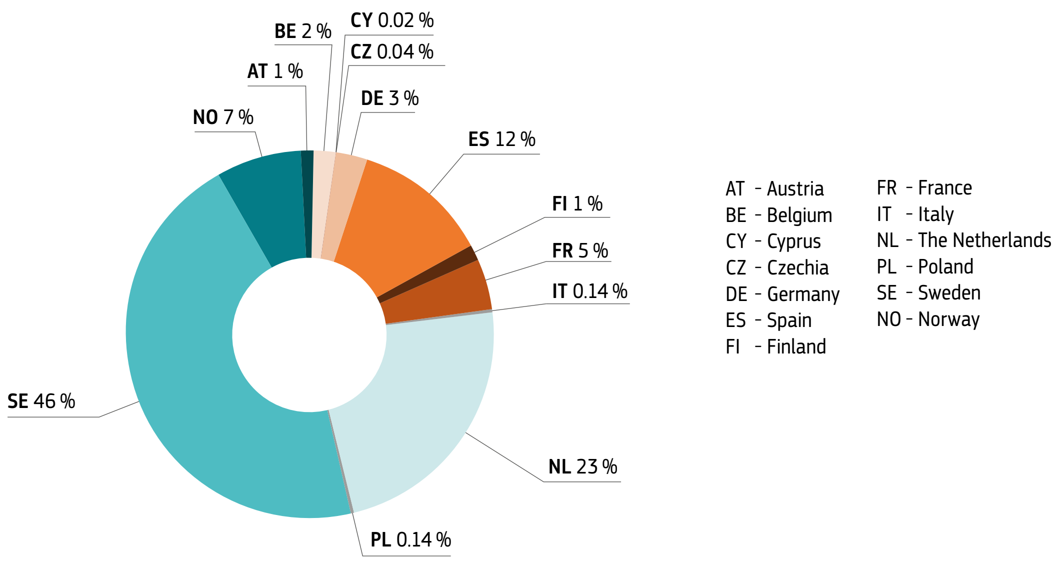
5.2. Hydrogen

PROJECTS WITH A HYDROGEN COMPONENT

The hydrogen cluster includes 33 ongoing projects with a CAPEX of around EUR 18 billion. Notably, 70 % of these are large-scale projects.

This cluster includes projects dedicated to renewable and low-carbon hydrogen production along with projects using renewable hydrogen to produce other final products such as methanol, ammonia, green steel and synthetic aviation fuel.

Figure 16. Share of hydrogen production per IF project implementing country.



In terms of the volume of renewable and low-carbon hydrogen produced per year, the projects in this cluster are expected to generate a total of 604 256 tonnes per year. Projects located in Sweden represent the largest share (46 %) of the cluster's foreseen hydrogen production, followed by the Netherlands with 23 % and Spain with 12 % (Figure 16).

Two major iron and steel projects located in Sweden, namely H_2GS and the Hybrit demonstration, contribute to 32 % of the total expected hydrogen production.

IIn terms of final products, 35 % of the projects generate renewable and low-carbon hydrogen as final products (Figure 17), while the others produce derivatives. The chemical sector, through the production of green ammonia and green methanol, contributes to 18 % of the production and usage of hydrogen. The remaining 15 % of the produced hydrogen is allocated for the production of green fuels, both bio and synthetic (e.g. sustainable aviation fuel).

Figure 17. Share of hydrogen production per final product (excluding manufacturing of components for electrolysers).

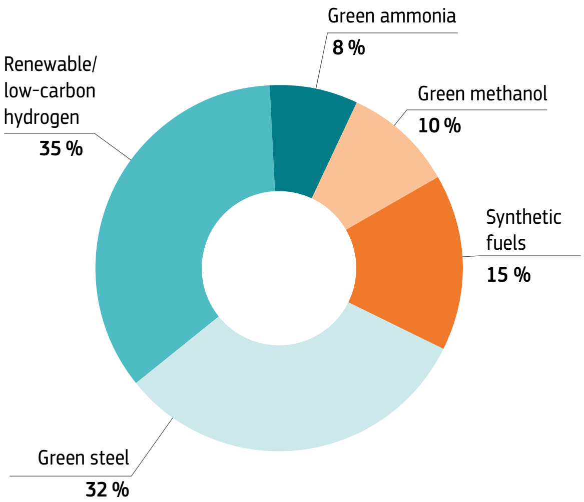
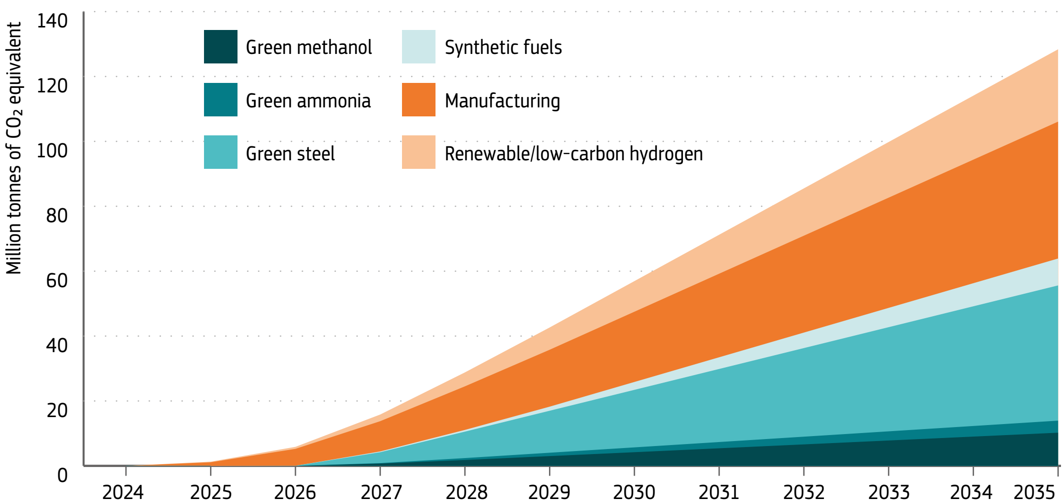


Figure 18 shows the expected cumulative GHG emission avoidance for various final products. It is expected that the first hydrogen projects will reach FC by the end of 2024, while the remaining projects are expected to reach this stage in 2025. As for the EIO, most projects expect to initiate production between 2025 and 2027.

Concerning the hydrogen production technology pathway, 42 % of the projects will implement alkaline electrolysers, 27 % proton exchange membrane electrolysers, 7 % hybrid (alkaline + proton exchange membrane) electrolysers, 7 % municipal solid waste gasification and 3 % photoelectrocatalysis. The remaining 14 % of the projects have still not finalised the set-up of the technology.

Figure 18. Expected cumulative GHG emission avoidance per type of project in the hydrogen cluster.



CHALLENGES AND KEY MESSAGES

Securing essential equipment and supply contracts, particularly for electrolysers, poses a challenge in the EU market due to the increasing costs and potential scarcity of key electrical components such as switchgears. **Strategic planning, effective engineering, procurement and construction contractor management and early engagement (and partnership) with suppliers** were among the key mitigation strategies adopted by projects.

Nevertheless, one of the greatest challenges for the advancement of hydrogen projects remains **complying with the requirements of the RED Delegated Act for non-biological renewable fuels (RFNBOs)**, requiring projects to secure a sustainable supply of renewable electricity. The additional requirements are highly demanding for large-scale projects, especially the requirement of certification and post-2030 hourly correlation, as defined in the RED Delegated Act for RFNBOs. Failure to comply with requirements poses the risk that some shares of the produced hydrogen may not meet the RFNBO requirements, prompting uncertainty in business cases and contractual terms with offtakers. Moreover, projects that use recycled carbon fuels are emerging amidst uncertainties in the regulatory framework, such as in the case of the EU hydrogen and decarbonised gas package ([21]), agreed at the political level at the end of 2023.

Furthermore, to **meet legal obligations**, projects must make a series of strategic decisions to optimise their renewable energy supply. This includes estimating the surplus of renewable energy needed to guarantee the production of RFNBOs and combining various intermittent renewable portfolios to achieve satisfactory full load hours. Another example in this sense is the selection of appropriate electrolyser technology, balancing out costs and production flexibility.

Other challenges pointed out by the projects are the **illiquid power purchase agreements markets**, in which supply and demand for power purchase agreements are not balanced. **Long permitting processes** for renewables energy installations and grid connection create additional bottlenecks in securing the renewable power supply.

Figure 19.
Project FUREC – transforming non-recyclable solid waste streams into hydrogen and providing circular feedstock to the chemicals industry.

([21]) EU hydrogen and decarbonised gas package: https://europa.eu/!YPpd33.

Besides legal and regulatory constraints, **securing financing** for hydrogen projects remains challenging due to banks' reluctancy to finance them. The banks see the risks in technology uncertainties mainly due to size of the scale-up of new technologies and lack of back-to-back agreements between energy suppliers and offtakers. The primary option for debt financing remains **corporate loans with support from a parent entity**. For fully equity-financed projects, **bank refinancing after EIO** is also an option. Experience gained from projects has shown that **integrated projects and long-term offtake contracts with price hedging strategies** may be required to secure non-recourse financing from banks.

Additional constraints tend to emerge when projects attempt to secure **long-term offtake agreements** for renewable hydrogen. The absence of a stable renewable hydrogen reference price and the existence of infrastructure limitations, such as the shortage of hydrogen pipelines, narrows down the pool of possible offtakers. In search of a solution, certain projects are looking to **establish partnerships with offtakers**.

5.3. Carbon capture and storage

PROJECTS WITH A CCS COMPONENT

CCS projects are flagship projects that contribute strongly to the objectives of the EU's industrial carbon management strategy ([22]). There are 16 ongoing IF projects that rely on CCS solutions. These projects have a total CAPEX of more than EUR 5.4 billion, with an IF contribution of EUR 2.6 billion. Most of the projects are located in western Europe, followed by Greece and Iceland.

The portfolio consists of 15 large-scale projects (including a pilot project) and one small-scale project. They address all elements of the value chain of carbon capture, transport and storage across Europe.

Two IF projects, ANRAV and Silverstone, aim to demonstrate the full value chain covering CO_2 capture and permanent storage. ANRAV, in Bulgaria, includes CO_2 capture at the cement plant and CO_2 transport by a pipeline to the permanent carbon storage in a depleted oil and gas field in the Black Sea. Silverstone will demonstrate the CO_2 capture from a geothermal power plant and its permanent storage as carbonate minerals in basaltic rocks in Iceland. Silverstone is the first CCS project of the IF that reached the FC milestone.

([22]) EU industrial carbon management strategy: https://europa.eu/!b7QDbf.

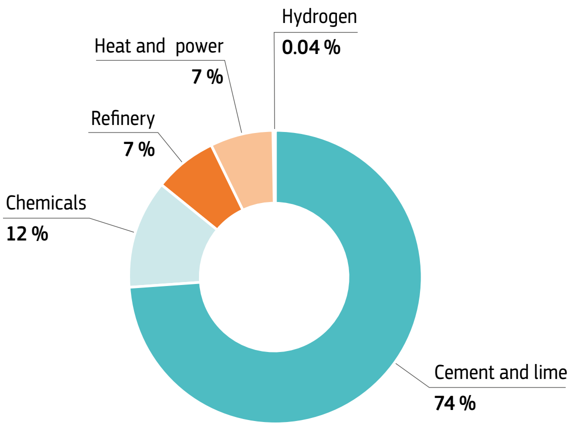
CO_2 CAPTURE

Most of these CCS projects concentrate their activities on the capture side, including the CO_2 compression and liquefaction infrastructure. Transport and storage are to be developed mainly outside the project boundaries by external service providers.

Substantial volumes of CO_2 are expected to be captured by IF projects as of 2027–2028 with the EIO of eight large-scale projects (projects ANRAV, Beccs Stockholm, CalCC, GO4ECOPLANET, IRIS, K6, Kairos@C and KOdeCO net zero) with a total volume of 5.8 million tonnes of captured CO_2 per year. The EIO of five more projects is expected between 2029–2030 (projects EVEREST, GeZero, GO4ZERO, IFESTOS and OLYMPUS).

Overall, the projects expect to capture around 12 million tonnes of CO_2 equivalent per year by 2030 thanks to support from the IF. The main source of captured CO_2 is the production process of cement and lime. CO_2 captured by source in the IF projects and its corresponding share is presented in Figure 20.

Figure 20. CO_2 captured by source in the IF projects.



Additionally, approximately 0.6 million tonnes of CO_2 captured per year will contribute to the net carbon removals originating from a biomass CHP plant in project Beccs Stockholm. Further negative emissions of at least 0.6 million tonnes of CO_2 equivalent per year are expected from the organic fraction of refuse derived fuels used in some of the cement and lime plants. At least 1.2 million tonnes of CO_2 per year will make up the carbon removals eligible for certification through the EU voluntary framework for high-quality carbon removals. This accounts for approximately 11 % of the total CO_2 to be captured and stored by the IF projects.

In terms of the capture technology deployed, most of the projects (11) use Cryocap capturing technology, while amine-based CO_2 capture is only applied by two projects. Project Beccs Stockholm implements a hot potassium carbonate technology, previously demonstrated at their on-site pilot-scale plant. Project CFCPILOT4CCS uses carbonate fuel cells (CFC) to capture CO_2 from dilute industrial streams.

CO_2 TRANSPORT

Captured CO_2 that is not intended for use on site must be compressed for transport by pipeline, ship, barge or rail. Most projects rely on the development of CO_2 transport networks. CO_2 export terminals or hubs located in ports enable the long-distance transport of large volumes of CO_2 via dedicated vessels. Such infrastructure is supported by CEF Energy ([23]), another EU programme managed by CINEA. For the time being, three CEF-supported infrastructure projects will enable the transport of CO_2 via pipelines and the export of CO_2 from five IF projects contributing to the creation of a CO_2 value chain in Dunkirk (CalCC and K6 connected to D'Artagnan CO_2 hub ([24])), Antwerp (Kairos@C and Antwerp@C ([25])) and Rotterdam (CFCPILOT4CCS connected to Porthos ([26])).

Projects ANRAV and Kairos@C address transportation within their project boundaries by building pipelines or ships and portside facilities. For example, project Kairos@C, in Belgium, will build and use vessels to transport liquified CO_2. Railway or pipelines are the most common alternative for IF projects that are located far from maritime ports.

More information about the location of IF projects and synergies with the CEF-supported infrastructure can be found on the dedicated website Industrial Carbon Management: Interactive Stories ([27]).

Figure 21.
Project CFCPILOT4CCS – developing an innovative decarbonisation solution by using CFCs to capture and concentrate CO_2 lean streams.

([23]) Energy infrastructure (Connecting Europe Facility): https://europa.eu/!nnqtpF.

([24]) D'Artagnan Dunkirk CO_2 hub: https://europa.eu/!xfcwX4.

([25]) Antwerp Liquid CO_2 Export Terminal Studies: https://europa.eu/!D4dR6f.

([26]) Porthos CO_2 transport network: https://europa.eu/!QXYYqp.

([27]) Industrial Carbon Management: interactive stories: https://arcg.is/1eiWr1.

CO_2 STORAGE

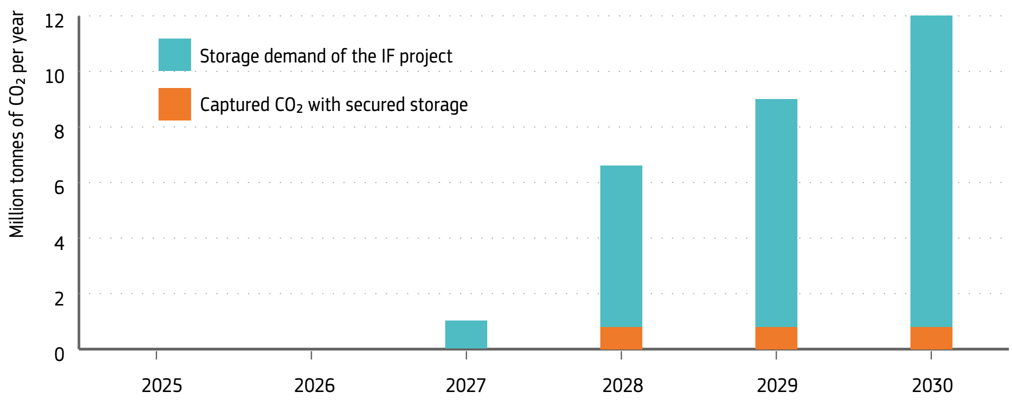
On the storage side, the Net Zero Industry Act ([28]) (NZIA) recognises CCS as a strategic net-zero technology and sets an annual injection capacity of at least 50 million tonnes of CO_2 to be achieved by 2030, in storage sites located in the EU. The CO_2 volumes to be captured by the IF projects can fill almost 25 % of the required storage capacities, starting as early as 2027.

The IF supports three projects developing CO_2 storage sites. Projects ANRAV and Silverstone will develop storage sites within their respective project boundaries. ANRAV is the first full value chain IF project incorporating all three elements of the value chain, including transport by pipeline and geological storage in a depleted hydrocarbon field. Silverstone will demonstrate a novel mineralisation technique of geological storage of CO_2 in basalt rocks (where the CO_2 reacts with the minerals and forms stable carbonate minerals). Project Coda Terminal demonstrates the mineralisation CO_2 storage method at a large-scale, also involving CO_2 transport via sustainable propulsion ships to Iceland. Its planned EIO is in 2026. The maximum storage capacity of 3 million tonnes CO_2 per year is planned to be operational from 2031.

All other IF projects plan to contract storage capacity and, in most cases, transport services from operators providing such services outside of their project boundaries.

For example, the CFCPILOT4CCS project is the first IF project with secured storage capacity for its relatively small volumes at the Porthos project (Port of Rotterdam CO_2 Transport Hub and Offshore Storage) in the Netherlands. The rest of the projects capturing CO_2 (12) have a total storage demand of 11.2 million tonnes of CO_2 equivalent per year by 2030 (Figure 22). For these projects, storage capacity still needs to be contracted.

Figure 22. The annual carbon capture rate and storage needs of IF projects based on the GHG absolute emission avoidance.



([28]) The Net-Zero Industry Act: https://europa.eu/!THBKQD.

CHALLENGES AND LESSONS LEARNED

With the notable exception of project Silverstone, all CCS projects have not yet reached FC. For projects to advance, several challenges need to be overcome in the upcoming years, some of which are independent of the projects, instead being related to the emerging regulatory framework and market developments in a novel sector of activity. These challenges can be divided into three categories: CO_2 capture projects looking for CO_2 storage, projects with CO_2 storage in the boundary of the project and net carbon removal projects.

First, projects that are concentrated on the capture side need to contract external service providers for transporting and storing the captured CO_2. The main challenge encountered by projects is the **limited availability of CO_2 storage sites on the market within their relevant time frames.** There is currently only one storage site in the EU that has a CO_2 storage permit in place and that will enter into operation before 2030. Among the 13 projects that rely on external CO_2 storage services beyond their respective project boundaries, only one has successfully secured a storage contract. The imbalance between storage demand from planned capture projects and the availability of operational storage capacity significantly impedes market growth and increases **uncertainty around storage costs and the complexity of contractual risk-sharing discussions** between parties across the value chain. Timely operational availability of storage capacity at reasonable prices and access to CO_2 storage sites are of utmost importance if these projects are to reach their full potential.

Equally crucial is the need for **risk-sharing and risk-management mechanisms** to be addressed across the full value chain. Common **CO_2 standards** for transport infrastructure and CO_2 injection addressing the needs of all stakeholders are a prerequisite for the projects to achieve FC. At the same time, considering the nascent stage of the market, **alignment between market participants along the value chain in terms of maturation and investment decisions is needed**.

Even when the CO_2 storage site is developed within the project boundaries, projects face notable risks, particularly regulatory constraints. Projects that develop CO_2 storage sites within their project boundaries face challenges in applying the **CCS directive provisions, and in addressing permitting needs for CO_2 storage sites** in a timely manner. Even though the CCS directive has been transposed in all Member States, it has been applied in practice only in the Netherlands, where a CO_2 storage permit was issued. CO_2 storage permitting remains a first-of-a-kind activity in the other Member States for both managing authorities and prospective CO_2 storage site operators, hence raising significant permitting challenges. This becomes even more important in the context of the NZIA, which introduces the requirement for Member States to facilitate and speed up permitting processes for net-zero projects, including CCS.

Furthermore, projects generating net carbon removals face difficulties in **monetising the generated negative emissions**. Industrial carbon removals are not currently covered by the EU ETS directive. Since the ETS does not recognise negative emissions, the capture and storage of biogenic and atmospheric CO_2 is not incentivised by the EU compliance carbon market price, and currently the only incentive at EU level comes from the IF. In this context, investment decisions for this type of operation mainly rely on state subsidies or voluntary carbon markets. The **EU-wide voluntary framework for the certification of high-quality carbon removals** agreed at political level ([29]) at the end of February 2024 is an important step towards improving the business case of such projects.

In general, all IF-supported projects are front runners that deploy first-of-a-kind carbon management solutions at industrial scale, discovering a number of operational challenges that the Commission has proposed to address ([30]). These include **exchanges and structured synchronised cooperation between public and private entities at EU and Member State leve**l, to ensure that regulatory and market prerequisites for projects development are to be in place as soon as possible, in view of securing investment decisions.

([29]) EU-wide certification scheme for carbon removals: https://europa.eu/!4TXHw6.

([30]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Towards an ambitious industrial carbon management for the EU (https://europa.eu/!4TXHw6).

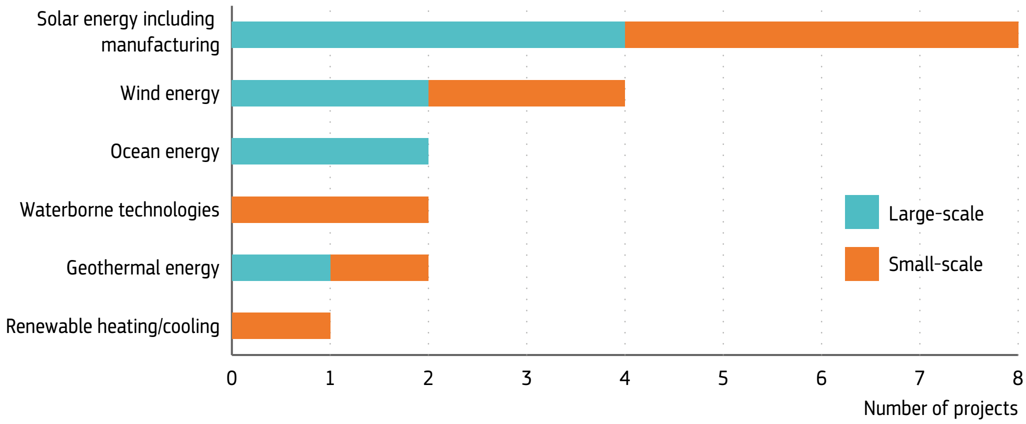
5.4. Renewable energy

PROJECTS WITH A RENEWABLE ENERGY GENERATION COMPONENT

The IF renewable energy cluster includes 19 ongoing projects with EUR 721 million of EU contribution and a total CAPEX of around EUR 4.5 billion. Most of the projects are located in Germany, France and Spain.

The cluster is composed of 10 small-scale and nine large-scale projects (Figure 23). Currently, most projects are focused on implementing innovations in solar and wind energy, while funded projects in ocean energy are two large-scale pilots.

Figure 23. Number and types of the projects in the renewable energy cluster.

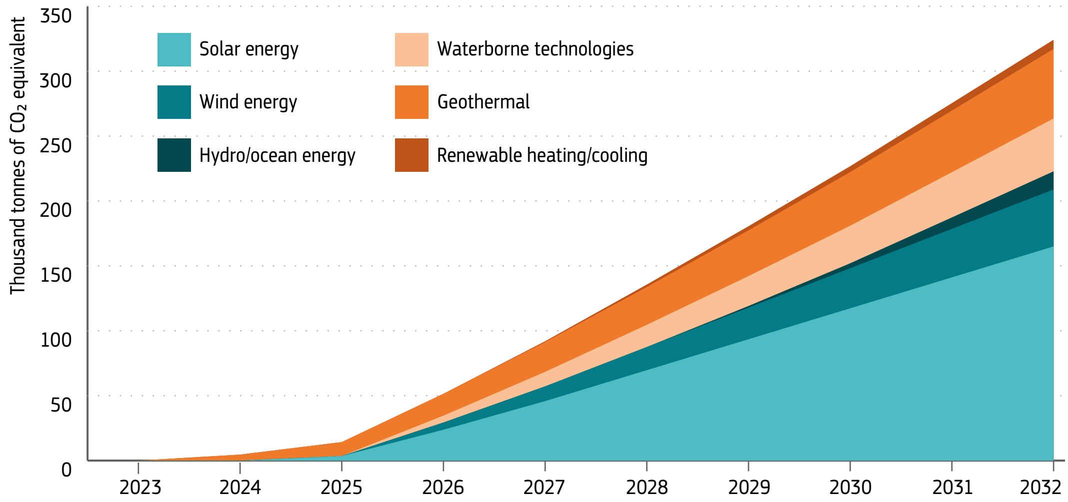


Overall, the projects of this cluster should support the generation of around 55 180 TWh of renewable energy during their lifetime.

By the end of 2023, four projects successfully reached FC: three targeting the solar industry (projects AGRIVOLTAIC CANOPY, Helexio line and TANGO) and one implementing renewable heating/cooling solutions (project WH).

The first renewable energy projects expected to enter into operation in 2024 are mainly small-scale projects, such as those focusing on solar energy technologies (e.g. project AGRIVOLTAIC CANOPY). Most small-scale projects are planned to enter into operation in 2025 (Figure 24).

Figure 24. Expected cumulative GHG emission avoidance per type of small-scale and pilot project in the renewable energy cluster.



Four out of six large-scale projects (excluding pilots) of the renewable energy cluster are targeting the manufacturing of components for solar energy, which explains the large expected GHG emission reduction (Figure 25). The first large-scale project, the photovoltaic (PV) gigafactory TANGO, is expected to enter into operation in 2024. The remaining large-scale PV manufacturing and wind energy projects are expected to enter into operation between 2025 and 2027.

Figure 25. Expected cumulative GHG emission avoidance per type of large-scale project (excluding pilots) in the renewable energy cluster.

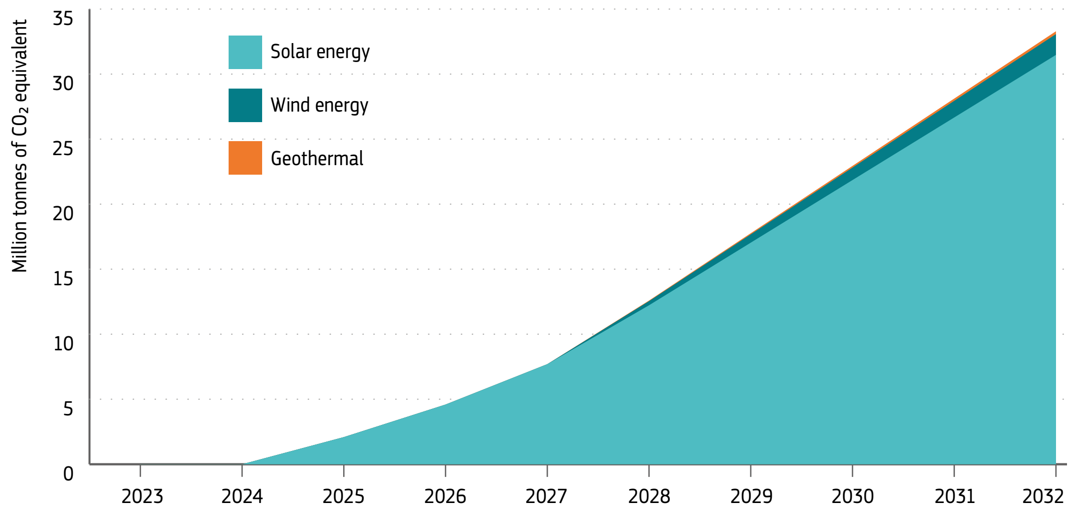


Figure 26.
Project TANGO – scaling up the production of high-performance PV modules in Italy, incorporating innovative bifacial heterojunction cells and tandem structures to significantly enhance efficiency and energy output, contributing to Europe's renewable energy capacity and competitiveness in PV manufacturing.

SOLAR ENERGY

Most solar PV manufacturing projects in the IF portfolio are large-scale projects. They span across the entire value chain: from ingots and wafers (project SunRISE) to c-Si cells and modules (projects TANGO and HOPE), CIGS modules (project DAWN) or modules for building integrated PV applications (project Helexio line).

On the other hand, projects aiming at solar-based energy production are all small-scale and are often combined into bigger concepts or existing facilities. For example, project AGRIVOLTAIC CANOPY features a 2.9 MWp system installed at five meters over agricultural surfaces. Project CO_2-FrAMed aims to install 7.35 MWp of solar power for zero carbon irrigation systems.

WIND ENERGY

Wind energy projects, mainly located in central and northern Europe, drive technological advancements by demonstrating a unique technology or a combination of technologies. During the projects' lifetime, the expected overall electricity production of the four wind energy projects is 18.6 TWh.

An example of combined technologies involves the deployment of an offshore wind farm with a capacity of 450 MW coupled with on-site hydrogen production (project N2OWF). Another example is the project Aquilon which implements airborne wind energy technology combined with a solar PV and redox flow battery storage.

HYDRO/OCEAN ENERGY

There are two ocean energy projects demonstrating wave energy technologies: SAO in Ireland and SEAWORTHY in Spain. Project SAO operates in a 5 MW array, while project SEAWORTHY combines wave energy solutions (0.8 MW wave energy converter) with other renewable energy solutions (e.g. a 4.3 MW wind turbine), a 1 MW electrolyser and incorporates a 48 MWh hydrogen energy storage and 1.2 MW fuel cell.

WATERBORNE TECHNOLOGIES

In France, project HyPush and, in Spain, project SustainSea showcase innovations aimed at decreasing GHG emissions. The former achieves this by integrating hydrogen technology into existing propulsion systems, while the latter supports propulsion with renewable solutions, using large-scale innovative rigid wind sail systems.

GEOTHERMAL ENERGY

Two IF projects are focused on the deployment of innovative geothermal technologies. For example, project EAVORLOOP in Germany aims to produce renewable power and heat using geothermal heat and advanced combined power generation cycles.

RENEWABLE HEATING AND COOLING

The IF currently supports one small-scale grant in this field. Project WH, in France, demonstrates an innovative mobile thermal storage technology at commercial scale, facilitating the recovery of high-temperature waste heat. The stored heat is then transported to a sport complex, providing renewable heating and cooling services.

Figure 27.
Project WH – innovative mobile thermal battery charged with recovered heat from a waste incinerator. The stored thermal energy will then be made available at a sports complex located 20 km away.

CHALLENGES AND LESSONS LEARNED

The renewable energy projects are facing some of the common challenges (see point 4.2). These include **cost increases** and difficulties in securing **offtake contracts**.

European PV manufacturers within the IF portfolio report that their **production costs exceed market selling prices**, leading to non-profitable business models. The mitigation strategies explored include **developing higher-quality products at premium prices** or **seeking state-aid support and market protection mechanisms**.

Several projects report issues in raising the necessary funds to reach FC, given the **competition from other funding mechanisms**. According to projects, more generous and accessible subsidies elsewhere can divert projects and financiers. Multi-sectoral projects, or those demonstrating novel technologies, often face challenges due to **local authorities' lack of experience in permitting or regulatory matters**. For example, the use of innovative fuels, the implementation of offshore innovations or deploying airborne technologies may require specific permits or authorisations that have not yet been regulated. This leads to delays and uncertainties, impacting the timing and business viability of some projects. Projects typically **engage with permitting authorities** early on and carefully plan to address uncertainties. In some cases, **specialised advice is sought** from outside the project consortium.

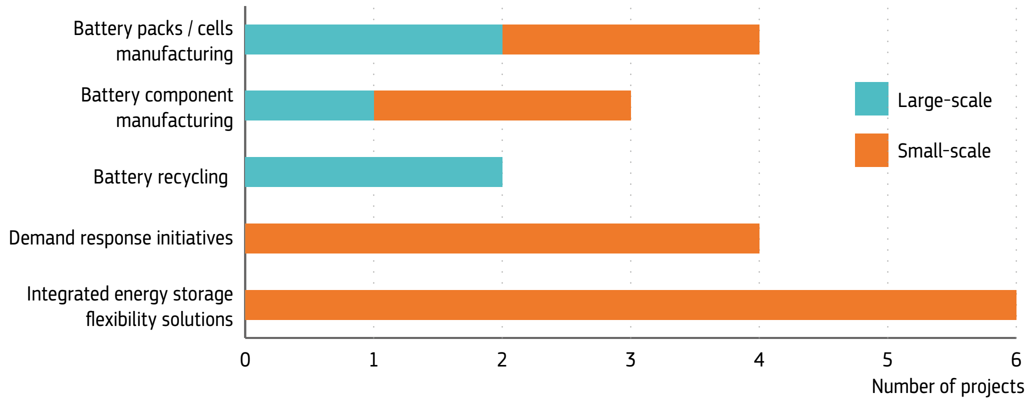
5.5. Energy storage

PROJECTS WITH AN ENERGY STORAGE COMPONENT

The energy storage cluster consists of 19 projects addressing various aspects of energy storage system value chains with an IF contribution of almost EUR 480 million and a total CAPEX exceeding EUR 5.4 billion. These projects are located in 12 countries.

In this cluster are five large-scale projects exclusively focusing on new battery-related manufacturing and recycling lines (Figure 28). These projects represent 98 % of the above mentioned CAPEX.

Figure 28. Number and types of projects in the energy storage cluster.



BATTERY MANUFACTURING AND RECYCLING

Projects aiming at establishing a full manufacturing and recycling cycle for battery systems (31) include manufacturing processes for battery cells and packs (projects Giga Artic, NorthFlex, and NorthSTOR+) and for essential battery components (projects ELAN, Green Foil, and Listlawelbattcool). Other manufacturing projects focus their efforts on assembling lines for sustainable EV battery reuse in stationary storage (project CarBatteryReFactory) and recycling critical and strategic (32) raw materials (projects BBRT and ReLieVe).

Battery packs and cells manufacturing projects are expected to produce around 2 019 GWh of additional battery storage capacity, mainly from the sites located in Norway and Poland. Projects involving the manufacturing and recycling of battery components (33) aim to enable the production of around 24 812 GWh of additional battery storage capacity, mainly from the plants located in Czechia and Norway. The substantial difference in capacity creation is attributed to innovations in battery chemistries, including the advancements in electrode materials or electrolytes and specific components like the battery cooler.

(31) Within this cluster we will refer to them as (1) battery packs /cells manufacturing, (2) battery component manufacturing, (3) battery recycling projects.

(32) Critical Raw Materials Act: https://europa.eu/!kdPp83.

(33) Such as aluminium foil, coolers or cathode materials, as well as projects recycling end-of-life batteries to obtain metals in the active materials for battery cells production.

ENERGY STORAGE SOLUTIONS

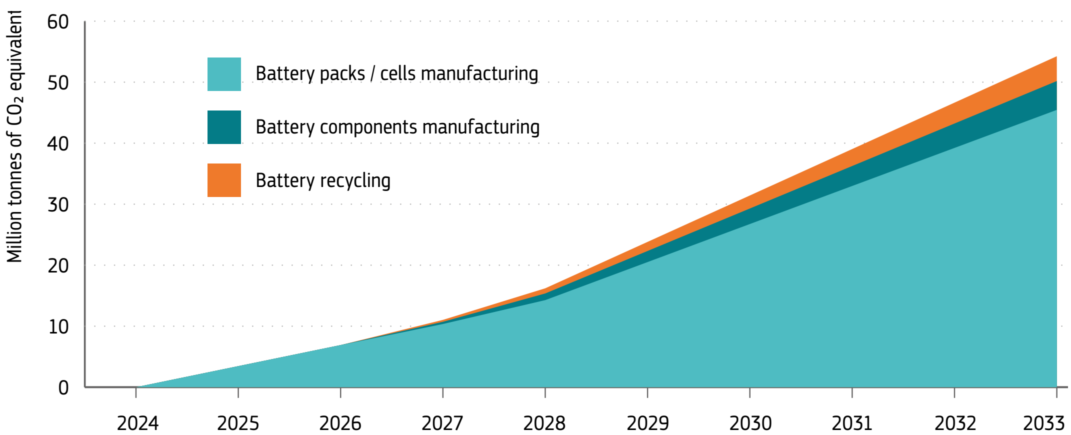
Projects developing local or grid-connected energy storage solutions ([34]) aim to optimise the use of resources, adapting demand response measures to local needs or facilitating intraday storage solutions. This improves grid stability and contributes to the decarbonisation of EIIs (project AAL SEB). Demonstrations of virtual power plants (project Green the Flex), sometimes integrated with bidirectional charging (V2G) solutions (projects EVVE and DrossOne), offer flexibility to align electricity demand with generation, shifting consumption to off-peak hours and generating revenue in the energy market. Others define trigger points for disconnection or load shifting according to local energy conditions (projects Aquilon and GREENMOTRIL) or manage excess energy in solar plants (project PIONEER), and some even demonstrate an innovative energy-as-a-service business model (project InnoSolveGreen). Integrated solutions include mobile thermal storage of heat recovered from incinerators (project WH).

Most projects offering energy storage solutions for local and grid applications prefer electricity as the energy carrier, thus taking advantage of its precise control, rapid energy transfer and compatibility with electronic devices. These demand response solutions cater to prosumers and V2G charging stations through seven projects, with a total capacity of 369 GWh, making major contributions in Lithuania and Italy. However, projects utilising heat demonstrate higher capacity compared to those relying on electricity as the primary energy carrier, as just three projects achieve a capacity of around 564 GWh. This is because they are designed for applications that inherently demand larger amounts of energy, such as high-pressure steam production or energy-intensive industrial processes. These projects are primarily located in France and Ireland.

Of the 19 projects in this cluster, seven small-scale projects and one large-scale project have reached FC and have started construction, while the remaining projects aim to reach this milestone between 2024 and 2025. Of the eight projects that reached FC, only one small-scale project (AAL SEB) has entered into operation and four more projects are expected to follow suit in 2024.

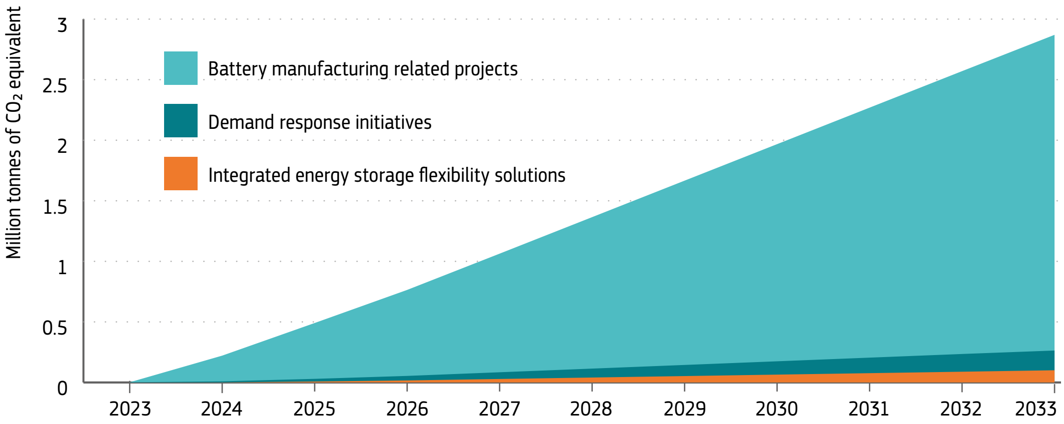
A significant majority (89 %) of projects within this cluster uses batteries or manufacturing plants for components as main technology pathways to contribute to achieving climate neutrality by 2050. Figure 29 and Figure 30 show the expected cumulative GHG emission avoidance for the coming years.

Figure 29. Expected cumulative GHG emission avoidance per type of large-scale project in the energy storage cluster.



([34]) Within this cluster we will refer to them as (1) demand response Initiatives and (2) integrated energy storage flexibility solutions.

Figure 30. Expected cumulative GHG emission avoidance per type of small-scale project in the energy storage cluster (excluding an outlier project).



CHALLENGES AND LESSONS LEARNED

The energy storage projects faced **challenges linked to the heterogenous permitting process or the regulatory framework in different Member States** (35). More established Member States' frameworks support the operation of EV storage and recharging systems by regulating the contractual relationship between the supplier and the independent aggregator (36). Namely, Member States that have made significant progress in developing this regulatory framework apply the perimeter correction (37) that allows for operation with multiple decentralised units.

To address this challenge, particularly in Member States where the regulatory framework is not well established or is in its early stages, projects prioritised **deploying bi-directional chargers BTM** (38), **while implementing explicit demand response strategies**. These measures aimed to optimise fleet charging schedules and improve the coordination and control of energy consumption patterns. Additionally, **explicit demand response** (39) **allowed for direct participation in energy markets**, such as reserve markets, enhancing grid flexibility in real time. Moreover, lessons learned from project implementation underlined the **necessity to intensify efforts to develop EU standards** (40) on metering and sub-metering systems, ensuring interoperability and access to real-time monitoring

(35) Fast charging poses still some challenges, such as hardware and design complexity and battery degradation concerns.

(36) The actions of independent aggregators affect suppliers and the balancing responsible party (BRP) designated by the supplier. The BRP can be the supplier itself or a third party. EUI Working Paper RSC 2021/53: https://hdl.handle.net/1814/71236.

(37) A straightforward way to correct the imbalance of the supplier's balancing responsible party (BRP) due to the actions of the independent aggregator is through a so-called 'perimeter correction'. With a perimeter correction, the imbalance of the supplier's BRP is corrected with the metered volume of energy activated by an independent aggregator's action. This corresponds to an extension of the imbalance adjustment to third party BSPs, including for bids in markets other than the balancing energy market. The correction is done *ex post*, in most cases by the transmission system operator. As such, the supplier's BRP is not held responsible for actions it cannot act upon. EUI Working Paper RSC 2021/53: https://hdl.handle.net/1814/71236.

(38) BTM installations consist of placing energy generation and storage systems on the consumer side of the utility meter. This allows users to generate, consume and store energy locally without relying solely on the grid.

(39) Depending on national legislation, BTM energy storage systems installations can actively participate in both the energy market and the balancing market, offering valuable services to the grid such as frequency stability and voltage stability.

(40) The gap between the number of Member States where independent aggregation is enabled (19) and those where it also exists in practice (7) has to do with market barriers (e.g. unclear business case), regulatory barriers (e.g. lack of secondary legislation defining responsibilities) and technology constraints (e.g. lagging roll-out of smart meters), and is also linked to the particular conditions in each Member State and its approach to explicit demand response as a resource. Saviuc, I., Lopez, C., Puskas, A., Rollert, K. and Bertoldi, P., *Explicit demand response for small end-users and independent aggregators – Status, context, enablers and barriers*, EUR 31190 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-55850-7, doi:10.2760/625919, JRC129745.

data. This is key for the rapid deployment of standardised and fast-charging [41] V2G stations.

With the goal of **increasing the percentage of recycled metals in new battery cells** and thus promoting closed-loop battery recycling, projects are exploring various processes within battery recycling lines. The objective is to identify metal salts that maintain the required metal recovery rate and are also suitable for manufacturers of cathode active materials and precursor products.

Furthermore, incentives and **business models** are often shaped by each Member State's unique energy transition goals, market conditions and political considerations. Projects encountered challenges in defining viable business models for the deployment of thermal storage in district heating systems, V2G station deployment and end-of-life battery recycling projects. Projects signed **binding agreements with offtakers** to reduce risk in their business models and provide confidence to potential investors. To further de-risk the implementation, these projects adopted an **SPV ownership model** and presented a simplified approach to financing by **investing own funds (equity), in addition to a debt facility and the application for EU grants**.

Second-hand battery reuse projects, end-of-life battery recycling projects and V2G-related projects presented an approach to de-risk their business models by **consolidating partnerships along their value chain** (integrating equity partners, banks, suppliers, transporters and other intermediaries in their consortium). This type of initiative has proven to be useful in reducing the risk of such investments and in increasing harmonisation in technology development (e.g. of the bi-directional charging with the combined charging system standard) and final product specifications (e.g. in terms of purity and volume of metal salts).

Heat-as-a-service projects also explored viable business models by **considering additional revenue streams from using heat pump activation and deactivation to support grid stability**. The service's design is closely tied to customer specifications, addressing challenges posed by national regulations. For example, in countries like Denmark, where market revenues face limitations due to regulated margins, revenue primarily comes from selling heat to specific customers through tailor-made agreements. However, this dependency on specific customers and technology suppliers tailored to their needs impacts the projects' risk profile.

The timely implementation of projects was hindered by challenges arising from **supply chain disruptions, causing higher costs due to prolonged lead times, and shortages of critical equipment**. Lithium-ion battery manufacturing projects tackled these challenges through **proactive strategies such as advance procurement planning, local sourcing and strategic stock management**. Similarly, projects with energy storage systems, including those focused on virtual power plants, faced shortages in procuring essential equipment, prompting strategic adjustments to initial plans that did not impact project objectives. These adaptations included **reducing the storage power parameter, creating extended periods of charging and discharging, while retaining the initial storage capacity, and integrating a mix of new and second-life batteries** to aid the transition to alternative battery systems for long-term cost savings and enhanced availability.

‹

Figure 31.
Project CarBatteryReFactory – developing, building and operating a new site for manufacturing energy storage systems based on end-of-life and second-life batteries.

(41) Fast charging still poses some challenges, such as hardware and design complexity and battery degradation concerns.

6. OUTLOOK FOR 2024

In 2024, the projects in the IF portfolio are expected to continue maturing. According to current insights from project beneficiaries, 33 projects are expected to reach FC and 10 projects are expected to enter into operation. In addition, the IF portfolio will increase its number of projects.

In December 2023, the Commission announced the selection of 17 small-scale innovative cleantech projects to receive over EUR 65 million in project support under the IF ([42]). The grants are expected to be signed in June 2024. If the grant agreement preparation process meets the expectations, the IF portfolio will include the first projects located in Hungary and Latvia.

In 2024, the two calls opened in 2023, one for lump-sum grants and another for the pilot EU renewable (RFNBO) hydrogen auction, will conclude, providing at least EUR 4.8 billion for industry and cleantech players in Europe.

In particular, the IF23 call for lump-sum grants (INNOVFUND-2023-NZT) will award at least EUR 4 billion to innovative decarbonisation projects in various sectors, including EIIs, renewables, energy storage, CCS, and net-zero mobility and buildings. The application window closed in early April 2024. With the revision of the EU ETS directive and the extension of the ETS scope to three new categories, the current call will include new sectors, namely maritime transport, aviation and buildings. Furthermore, a new category of projects, medium-scale projects, has been introduced in the grant calls, to better meet market demand.

The RFNBO hydrogen auction call is the first of its kind in Europe that supports the production of RFNBO hydrogen in Europe under the European Hydrogen Bank ([43]). It has made a EUR 800 million budget available to bidders (project developers). Producers of renewable hydrogen can bid for support in the form of a fixed premium per kilogram produced. The premium is intended to bridge the gap between the price of production and the price consumers are currently willing to pay in a market where non-renewable hydrogen is still cheaper to produce.

Projects selected in the IF23 auction and in the IF23 call are expected to sign the grant agreements by November 2024 and March 2025, respectively.

In the last quarter of 2024, the Commission plans to initiate a new round of hydrogen auctions and launch the annual call for proposals.

Finally, the Commission (Directorate-General for Climate Action) and CINEA plan to organise three knowledge sharing events in 2024 to address challenges and share insights from projects. These events will focus on renewable energy, hydrogen and CCS. Additionally, the annual Cleantech Conference ([44]) in April 2024 concentrated on strategies to support the manufacturing of cleantech devices and their components in Europe.

([42]) Press release of 19 December 2023 – EU to invest over EUR 65 million in cleantech projects (https://europa.eu/!hF7Hx4).

([43]) Press release of 23 November 2023 – Commission launches first European Hydrogen Bank auction (https://europa.eu/!Bq7WVv).

([44]) Cleantech Conference 2024: https://europa.eu/!wvHTrt.

ANNEX – ASSIGNMENT OF THE INNOVATION FUND PROJECTS TO THE CLUSTERS

Project number and link to the project fiche	Project acronym	Call	Amount of IF grant (EUR)	Expected absolute GHG emission avoidance*	Main country of implementation	Assignment to the cluster1	Assignment to the cluster2
101038839	AAL SEB	InnovFund-SSC-2020	4 238 896	102 344	Ireland	EIIs	ES
101038931	AGGREGA CO_2	InnovFund-SSC-2020	3 168 000	28 364	Spain	EIIs	
101103027	AGRIVOLTAIC CANOPY	InnovFund-2021-SSC	2 756 167	6 982	France	RES	
101085939	AIR	InnovFund-LSC-2021	97 000 000	4 055 112	Sweden	EIIs	H_2
101085967	ANRAV	InnovFund-LSC-2021	189 694 949	7 801 634	Bulgaria	CCS	EIIs
101038976	Aquilon	InnovFund-SSC-2020	2 024 737	1 566	Germany	RES	ES
101133054	ASTURIAS H_2 VALLEY	InnovFund-2022-LSC	18 072 962	1 329 786	Spain	H_2	
101132908	BBRT	InnovFund-2022-LSC	100 000 000	2 257 326	Spain	ES	
101103445	BEAR	InnovFund-2021-SSC	2 238 000	96 384	Slovenia	EIIs	
101051202	Beccs Stockholm	InnovFund-LSC-2020-Two-Stage-2	180 000 000	7 834 149	Sweden	CCS	
101132801	BioOstrand	InnovFund-2022-LSC	166 648 512	8 762 169	Sweden	EIIs	H_2
101085879	C2B	InnovFund-LSC-2021	109 816 528	13 136 686	Germany	EIIs	
101086035	CalCC	InnovFund-LSC-2021	125 198 197	5 842 974	France	CCS	EIIs
101038902	CarBatteryReFactory	InnovFund-SSC-2020	4 499 400	1 391 601	Germany	ES	
101038843	CCGeo	InnovFund-SSC-2020	4 498 659	61 273	Croatia	RES	
101132998	CFCPILOT4CCS	InnovFund-2022-LSC	30 497 000	45 689	Netherlands	CCS	
101103342	CIRQLAR	InnovFund-2021-SSC	2 169 262	59 497	Spain	EIIs	

Project number and link to the project fiche	Project acronym	Call	Amount of IF grant (EUR)	Expected absolute GHG emission avoidance*	Main country of implementation	Assignment to the cluster1	Assignment to the cluster2
101103371	CLYNGAS	InnovFund-2021-SSC	4 416 864	406 960	Spain	EIIs	
101038836	CO_2-FrAMed	InnovFund-SSC-2020	4 356 000	17 702	Spain	RES	
101103194	CO_2ncrEAT	InnovFund-2021-SSC	4 265 136	190 967	Belgium	EIIs	
101085993	Coda Terminal	InnovFund-LSC-2021	115 000 000	21 101 419	Iceland	CCS	
101132829	Columbus	InnovFund-2022-LSC	68 600 000	1 874 305	Belgium	EIIs	H_2
101133214	DAWN	InnovFund-2022-LSC	32 265 535	1 073 343	Sweden	RES	
101039009	DMC	InnovFund-SSC-2020	4 499 338	43 691	Croatia	RES	ES
101038849	DrossOne V2G Parking	InnovFund-SSC-2020	1 643 000	63 432	Italy	ES	
101085560	EAVORLOOP	InnovFund-LSC-2021	91 600 000	439 735	Germany	RES	
101038915	EB UV	InnovFund-SSC-2020	2 400 000	35 374	France	EIIs	
101051308	ECOPLANTA	InnovFund-LSC-2020-Two-Stage-2	106 379 783	3 444 269	Spain	EIIs	
101132987	E-fuel Pilot	InnovFund-2022-LSC	40 000 000	228 163	Norway	EIIs	H_2
101133231	ELAN	InnovFund-2022-LSC	90 000 000	7 275 691	Norway	ES	
101132856	ELYAS	InnovFund-2022-LSC	51 926 000	23 441 943	Germany	H_2	
101085636	ELYgator	InnovFund-LSC-2021	99 000 000	3 314 197	Netherlands	H_2	
101133147	eM-Rhone	InnovFund-2022-LSC	115 190 750	2 325 243	France	EIIs	H_2
101133052	EnergHys	InnovFund-2022-LSC	75 000 000	2 091 499	Netherlands	H_2	
101132835	EVEREST	InnovFund-2022-LSC	228 721 666	9 309 295	Germany	CCS	EIIs
101039021	EVVE	InnovFund-SSC-2020	3 794 496	25 457	France	ES	
101038946	FirstBio2Shipping	InnovFund-SSC-2020	4 336 058	87 764	Netherlands	EIIs	

Project number and link to the project fiche	Project acronym	Call	Amount of IF grant (EUR)	Expected absolute GHG emission avoidance*	Main country of implementation	Assignment to the cluster1	Assignment to the cluster2
101086039	FUREC	InnovFund-LSC-2021	108 000 000	3 619 900	Netherlands	H_2	
101132475	GAP	InnovFund-2022-LSC	203 766 000	3 531 568	Norway	EIIs	H_2
101133005	GeZero	InnovFund-2022-LSC	190 905 744	7 265 868	Germany	CCS	EIIs
101133106	Giga Arctic	InnovFund-2022-LSC	100 000 000	27 847 298	Norway	ES	
101133022	GIGA-SCALES	InnovFund-2022-LSC	11 031 000	6 129 995	Belgium	H_2	
101085990	GO4ECOPLANET	InnovFund-LSC-2021	228 210 004	10 220 252	Poland	CCS	EIIs
101132807	GO4ZERO	InnovFund-2022-LSC	230 000 000	10 045 932	Belgium	CCS	EIIs
101132871	GRAMLI	InnovFund-2022-LSC	48 500 000	931 123	Austria	EIIs	H_2
101038874	Green Foil project	InnovFund-SSC-2020	2 676 706	36 883 571	Sweden	EIIs	ES
101133150	GREEN MEIGA	InnovFund-2022-LSC	122 917 845	2 901 078	Spain	EIIs	H_2
101102990	GreenH_2	InnovFund-2021-SSC	4 492 131	9 375	Poland	H_2	
101103240	GreenH_2CY	InnovFund-2021-SSC	4 499 877	21 677	Cyprus	H_2	
101038908	GREENMOTRIL	InnovFund-SSC-2020	4 347 980	29 152	Spain	ES	
101038856	GtF	InnovFund-SSC-2020	2 418 000	35 262	Austria	ES	
101038880	H_2 Valcamonica	InnovFund-SSC-2020	4 430 421	42 295	Italy	H_2	
101133206	H_2GS	InnovFund-2022-LSC	250 000 000	33 594 396	Sweden	EIIs	H_2
101038919	HELEXIO line	InnovFund-SSC-2020	3 733 140	169 929	France	EIIs	RES
101103063	HFP	InnovFund-2021-SSC	4 043 400	100 239	Netherlands	EIIs	
101085976	HH	InnovFund-LSC-2021	89 000 000	5 084 518	Netherlands	H_2	
101132817	HIPPOW	InnovFund-2022-LSC	30 000 000	55 424	Denmark	RES	
101132875	HOPE	InnovFund-2022-LSC	200 000 000	17 080 051	Germany	RES	

Project number and link to the project fiche	Project acronym	Call	Amount of IF grant (EUR)	Expected absolute GHG emission avoidance*	Main country of implementation	Assignment to the cluster1	Assignment to the cluster2
101051316	HYBRIT demonstration	InnovFund-LSC-2020-Two-Stage-2	143 000 000	14 296 430	Sweden	EIIs	H_2
101133035	HydrOxy	InnovFund-2022-LSC	49 212 730	1 292 898	Germany	H_2	
101132982	HyNCREASE	InnovFund-2022-LSC	5 224 360	3 922 533	Germany	H_2	
101103233	HyPush	InnovFund-2021-SSC	3 066 840	12 294	France	RES	
101085962	HySkies	InnovFund-LSC-2021	80 200 000	2 728 509	Sweden	EIIs	H_2
101038968	HYVALUE	InnovFund-SSC-2020	4 458 000	138 760	Spain	H_2	
101133204	IFESTOS	InnovFund-2022-LSC	234 000 000	20 227 227	Greece	CCS	EIIs
101103011	InnoSolveGreen	InnovFund-2021-SSC	2 614 114	16 669	Lithuania	ES	
101133015	IRIS	InnovFund-2022-LSC	126 790 000	8 585 470	Greece	CCS	EIIs
101051358	K6	InnovFund-LSC-2020-Two-Stage-2	153 386 598	8 118 812	France	CCS	EIIs
101051344	Kairos-at-C	InnovFund-LSC-2020-Two-Stage-2	356 859 000	13 959 782	Belgium	CCS	EIIs
101133120	KOdeCO net zero	InnovFund-2022-LSC	116 926 000	3 690 446	Croatia	CCS	EIIs
101103438	Listlawelbattcool	InnovFund-2021-SSC	3 651 974	223 570	Czechia	ES	
101038886	LK2BM	InnovFund-SSC-2020	4 488 046	142 925	Portugal	EIIs	
101132766	MoReTec-1	InnovFund-2022-LSC	40 000 000	823 484	Germany	EIIs	
101085995	N2OWF	InnovFund-LSC-2021	95 876 645	3 195 888	Germany	RES	H_2
101038892	NAWEP	InnovFund-SSC-2020	3 350 473	8 135	Norway	RES	
101038995	NorthFlex	InnovFund-SSC-2020	4 427 807	1 096 847	Poland	ES	
101085977	NorthSTOR PLUS	InnovFund-LSC-2021	75 451 457	34 519 213	Poland	ES	

Project number and link to the project fiche	Project acronym	Call	Amount of IF grant (EUR)	Expected absolute GHG emission avoidance*	Main country of implementation	Assignment to the cluster1	Assignment to the cluster2
101086023	OLYMPUS	InnovFund-LSC-2021	124 268 490	6 883 349	Greece	CCS	EIIs
101038964	PIONEER	InnovFund-SSC-2020	3 102 623	16 004	Italy	ES	
101103457	PRIMUS	InnovFund-2021-SSC	4 499 755	42 332	Italy	EIIs	
101085128	PULSE	InnovFund-LSC-2021	135 000 000	10 337 331	Finland	EIIs	
101086003	ReLieVe	InnovFund-LSC-2021	67 559 352	4 186 037	France	ES	
101133237	SAO	InnovFund-2022-LSC	39 475 000	26 245	Ireland	RES	
101133158	SC-HOOP	InnovFund-2022-LSC	16 193 000	139 838	Italy	EIIs	
101133097	SEAWORTHY	InnovFund-2022-LSC	26 000 000	25 557	Spain	RES	H_2
101051125	SHARC	InnovFund-LSC-2020-Two-Stage-2	88 286 266	4 036 901	Finland	H_2	
101038888	Silverstone	InnovFund-SSC-2020	3 867 988	149 970	Iceland	CCS	
101038876	SKFOAAS	InnovFund-SSC-2020	1 620 000	15 293	Spain	EIIs	
101103462	SOL	InnovFund-2021-SSC	4 000 000	44 736	Netherlands	EIIs	
101038951	SUN2HY	InnovFund-SSC-2020	4 484 293	23 209	Spain	H_2	
101133050	SunRISE	InnovFund-2022-LSC	53 600 000	4 936 138	Norway	RES	
101103465	SustainSea	InnovFund-2021-SSC	4 098 569	46 789	Spain	RES	
101051356	TANGO	InnovFund-LSC-2020-Two-Stage-2	117 675 100	25 043 106	Italy	RES	
101038816	TFFFTP	InnovFund-SSC-2020	4 200 000	70 865	Sweden	EIIs	
101133010	T-HYNET	InnovFund-2022-LSC	62 491 697	1 378 161	Spain	H_2	
101038899	TLP	InnovFund-SSC-2020	4 386 624	470 108	Sweden	EIIs	
101129002	TopSOEC	InnovFund-2022-LSC	94 000 000	7 580 000	Denmark	H_2	

Project number and link to the project fiche	Project acronym	Call	Amount of IF grant (EUR)	Expected absolute GHG emission avoidance*	Main country of implementation	Assignment to the cluster1	Assignment to the cluster2
101133213	TRISKELION	InnovFund-2022-LSC	48 846 672	860 282	Spain	EIIs	H_2
101102450	VITRUM	InnovFund-2021-SSC	4 100 000	25 597	Italy	EIIs	
101133064	Volta Project	InnovFund-2022-LSC	12 200 000	92 500	Czechia	EIIs	
101103370	VOZARTEK	InnovFund-2021-SSC	4 470 000	34 179	Czechia	H_2	
101038871	W4W	InnovFund-SSC-2020	2 452 401	131 161	Spain	EIIs	
101038978	WH	InnovFund-SSC-2020	2 456 505	12 806	France	RES	ES
101038982	ZE PAK green H_2	InnovFund-SSC-2020	4 460 000	77 331	Poland	H_2	

* Calculated according to the relevant GHG methodology (tonnes CO_2 eq).

More information about Innovation Fund projects is available in the CINEA dashboard: https://europa.eu/!8gQ67m

ABBREVIATIONS

BRP	balancing responsible party
BTM	behind the meter
CAPEX	capital expenditure
CCS	carbon capture and storage
CCU	carbon capture and utilisation
CO_2	carbon dioxide
EIIs	energy-intensive industries
EIO	entry into operation
EU ETS	EU Emissions Trading System
EV	electric vehicle
IF	Innovation Fund
FC	financial close
GHG	greenhouse gas
GWh	gigawatt hour
H_2	hydrogen
LSC	large-scale call
MW	megawatt
MWp	megawatt peak
NZIA	Net-Zero Industry Act
PV	photovoltaic
RED	renewable energy directive
RFNBO	renewable fuels of non-biological origin
SPV	special purpose vehicle
SSC	small-scale call
TWh	terawatt hour
V2G	vehicle to grid

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.

EUROPEAN CLIMATE, INFRASTRUCTURE
AND ENVIRONMENT EXECUTIVE AGENCY

https://cinea.ec.europa.eu/

CINEA on X

CINEA Clean Energy on X

LinkedIn

YouTube

Publications Office
of the European Union