EIC PATHFINDER PORTFOLIO

CARBON DIOXIDE AND NITROGEN MANAGEMENT AND VALORISATION PORTFOLIO

Strategic Plan

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Carbon dioxide and nitrogen management and valorisation Portfolio

European Innovation Council

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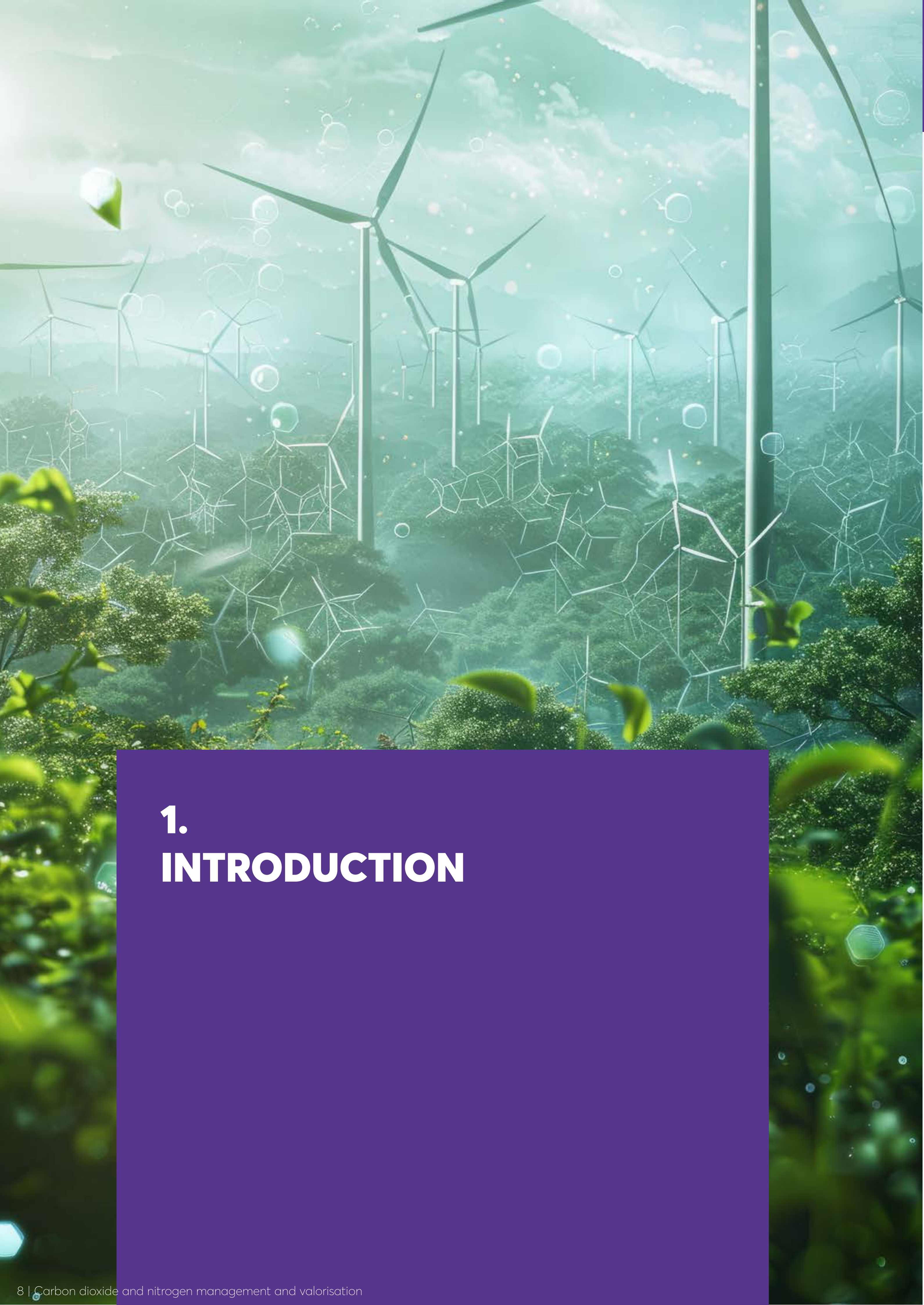


1. INTRODUCTION

1.1 BACKGROUND

Anthropogenic activities have strongly increased the CO_2 concentration in the atmosphere and highly impacted the global nitrogen (N)-compounds cycle in the past century. This affects climate change, depletion of oxygen into the water and uncontrolled growth of microorganism (eutrophication) and subsequent changes/loss in the structure, function and biodiversity of many ecosystems.

In this context, CO_2 and N-compounds cycles belong to the approach of 'make, use and dispose'. Their management includes capture, storage, processing to added value products and recycling. Implementing sustainable capture, conversion and utilization technologies for CO_2 and N-compounds cycles represents a key pillar to achieve net-zero emission targets and protecting ecosystems, as underlined in the European Green Deal goals. To achieve these by 2050, a range of breakthrough technologies, most of which not yet available on the market, is required.

The mitigation of and adaptation to climate change encompasses a broad range of interlinked strategies, which exceeds the pure capture of CO_2. These strategies should also address the combined capture and conversion of CO_2 and N-compounds into products, such as food and chemicals. By doing so, further emission reductions are also achieved. A number of studies prove how protecting and restoring wildlife and biodiversity strongly enhances carbon capture, and on the other side N-cycle is crucial to maintain intact ecosystems.

There is a clear need to address the nexus between carbon dioxide and nitrogeN-cycles in a holistic manner, in light of their important mutual impact on climate change and biodiversity of many ecosystems. It is therefore of critical importance to stimulate innovation of technologies for management and valorisation of CO_2 and N-compounds that facilitate the development and maintenance of environmentally sustainable supply chains.

1.2 THE CHALLENGE

In 2022, the EIC launched the **EIC Pathfinder Challenge "Carbon dioxide and nitrogen management and valorisation"**, which aims to develop novel **processes and technologies to capture and convert carbon dioxide** (CO_2) **and Nitrogen (N) into useful products**, and in turn to reduce (i) greenhouse gas (GHG) emissions; (ii) nitrogen losses mainly due to agricultural practices; and (iii) carbon losses from the energy, industrial, agricultural, and livestock sectors.

This Challenge focuses on new biological, chemical, and physical routes that integrate the capture and/or recovery of CO_2 and N species/compounds, their conversion into value-added products, chemicals, fuels or other energy vectors, for different use and applications. The processes should focus on the possible integration with renewable energy sources as input to develop carbon-negative or net-zero systems. Reaching these objectives requires multidisciplinary competencies and cross-sectorial approaches, with a strong focus on circularity and whole-life analysis.

The proposals selected in this call are expected to develop technologies for added-value products optimising input/output energy balances and achieving a carbon-negative or net-zero process, as well as investigating exploitation pathways and sustainable business models. Besides, the different steps of the CO_2/N management and valorisation processes could be designed to achieve integration at system or process level, to maximize sectors coupling. Some examples of this could be the conversion of renewable electricity into e-fuels and materials (e.g., power to X), to foster the decentralized production of materials, chemicals and fuels at the premises of the demand and close to the availability of input resources (i.e. point sources of CO_2 and N). Moreover, a specific focus of the portfolio will be on the identification of a merit order for the many concurring options to transform the input resources (CO_2, N) into valuable outputs, starting from the applications that maximize the overall benefits, and thus comparing the options of food, materials, chemicals and fuels production.

1.3 THE PORTFOLIO STRATEGIC PLAN

According to the call: "*Following the selection of proposals to be funded under the Challenge, the Programme Manager will work together with the selected projects to develop a common roadmap for the Challenge. This roadmap will integrate the activities and milestones of the individual projects into a shared set of objectives and cross-project activities. The roadmap serves as a common basis for implementing the projects - including possible adjustments, reorientations or additional support to projects - and can be updated considering emerging results or difficulties during the implementation. The objectives can be revised, for instance based on projects' unexpected achievements, new technology trends, external inputs (other projects, new calls…).*

In particular, the Challenge roadmap will include activities on the transition to innovation and commercialisation, and to stimulate business opportunities. These activities may be supported and reinforced during the implementation with additional funding and expertise through pro-active management."

This Portfolio Strategic Plan defines the objectives of the portfolio, identifies the activities to reach those objectives and guides their implementation by establishing a governance structure. The Portfolio Strategic Plan is the product of a collaboration between the portfolio projects, the Project Officers (POs) and the Programme Managers (PMs). The Portfolio Strategic Plan will be revised once per year. Further requests for an update can come either from the PMs, the POs, or the steering committee of the portfolio (see Governance).

Further details on the purpose of this Portfolio Strategic Plan are provided on page 11 of the Challenge Guide Carbon dioxide and nitrogen management and valorisation.

2.
THE PORTFOLIO

Table 1. Portfolio overview

ACRONYM	NUMBER	PROJECT DURATION	CONVERSION TECHNOLOGIES	PROJECT WEBSITE
Mi-Hy Microbial Hydroponics: Circular Sustainable Electrobiosynthesis	101114746	01/11/2023 31/10/2027	Biological (D)	www.mi-hy.eu/
HYDROCOW Hydrogen oxidizing bacteria engineered to valorize CO_2 for whey protein production	101115118	01/09/2023 31/08/2027	Biological (D)	www.hydrocow.eu
CONFETI Green valorization of CO_2 and Nitrogen compounds for making fertilizers	101115182	01/11/2023 31/10/2026	Hybrid – electrochemical/ photochemical and biological (E)	www.confetiproject.eu
ICONIC Integrated Conversion of NItrate and Carbonate streams	101115204	01/11/2023 31/10/2026	Electrochemical (C)	www.iconicproject.eu
ECOMO Electrobiocatalytic cascade for bulk reduction of CO_2 to CO coupled to fermentative production of high value diamine monomers	101115403	01/11/2023 31/10/2026	Hybrid – electrochemical/ photochemical and biological (E)	www.ecomo-eic.eu
SUPERVAL SUstainable Photo-ElectRochemical VALorization of flue gases	101115456	01/11/2023 31/10/2026	(photo) electrochemical (A)	www.superval.eu
DAM4CO$_2$ Double-Active Membranes for a sustainable CO_2 cycle	101115488	01/11/2023 31/10/2026	Photochemical (A)	www.dam4CO2.eu
MINICOR MILD Combustion with Nitrogen and Carbon Dioxide Reforming	101115506	01/11/2023 31/10/2028	Thermal conversion process (B)	www.minicor-project.eu

2.1

THEMATIC AREAS

The composition of the portfolio during the proposals evaluation was aimed at including a broad range of technologies to guarantee the diversification of CO_2 and N-compounds recovery and valorisation technologies. Diversity in systems integration options and scale of plant was also considered. The retained proposals constitute a portfolio covering a broad range of technologies with many final uses and different approaches for materials /components selection/optimization. A detailed overview of the portfolio is summarised in the portfolio website.

The proposals were classified into five technological areas, selected to capture the main conversion technologies of CO_2 and N-compounds, which are:

- **Area A:** Photoelectrochemical, photochemical, chemical
- **Area B:** Thermal
- **Area C:** Electrochemical
- **Area D:** Biological
- **Area E:** Hybrid (at least two equally important technologies)

In each technological area, the ranking of proposals was adjusted based on the following portfolio criteria specified in the Challenge Guide:

(i) potential collaborations with key stakeholders during the project implementation, including deployment strategy and the steps required to scale up the process;

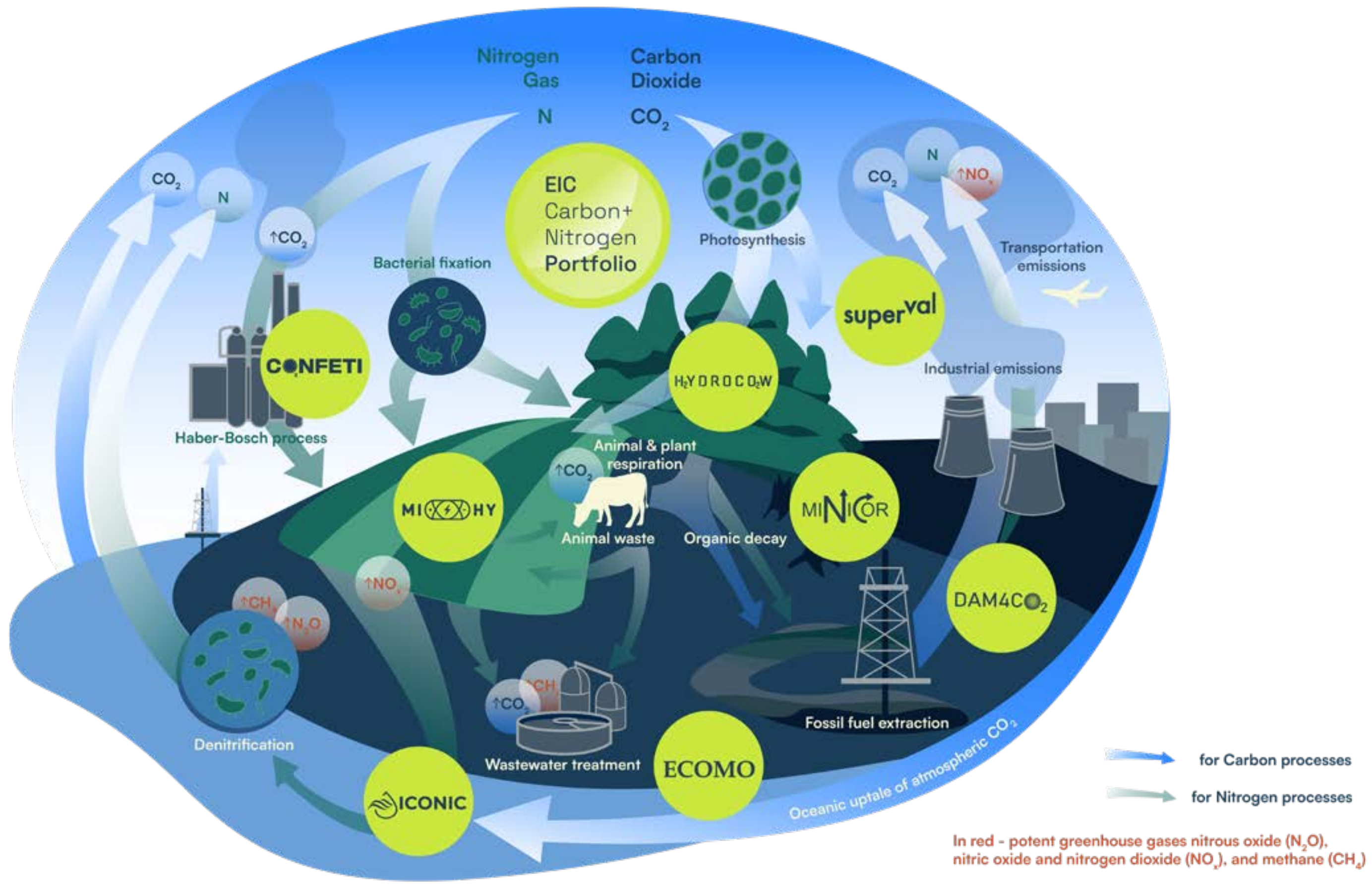
(ii) life cycle thinking, including the recovery and recycling of by-products;

(iii) safe use of non-environmentally harmful and non-critical raw materials (CRM), or the recycle/reuse of CRM;

(iv) addressing, if relevant, process or technology standardization/certification issues, safety/ regulations and performance of components/systems managing the whole process of the CO_2 and/or N-cycle.

The portfolio consists of 8 projects which started between 1 September 2023 and 1 November 2023 and will run for up to 60 months with a total granted EU contribution of around €29 million. Upon indication of the PMs, other projects funded from the EIC Pathfinder Open call can be invited to join the portfolio and/or participate in all or some selected activities. The retained proposals and their technological details are reported in Annex A.

Figure 1. C+N Cycle including projects



2.2

COMMONALITIES ACROSS PROJECTS

The potential synergies and complementarities among the projects were identified and reported in Table 1. The identification of further commonalities is also possible and will be actively explored during the execution of the projects and with the specific knowledge-sharing and networking tools put into practice.

Table 2. Areas of potential synergies among the portfolio projects

TECHNOLOGY	REGULATIONS	INNOVATION JOURNEY
Materials (such as bio- based, hybrid, inorganic) for CO_2 and N-compounds capture (sorbents), **conversion** (catalysts, bacteria), and **use**, including their physico-chemical characterization, the use of computational materials science "tools" for their design or screening, and the processing/ synthesis scale- up.	**Policy and regulations** enabling the development of novel technologies (and use-case scenarios) and **feedback to policy** enabling data-driven policies.	Exploitation strategies as part of the innovation journey: including **engagement with the final users** of the technology and of the future product, **market analysis** for the different fields of application and final products,
Input/feedstock, i.e., the source of CO_2 and N- compounds captured, supply chains and system integration opportunities (optimizing circularity via completing waste recycling).		
Accessing the required purity of the inputs both from the technological (e.g., existing or new technologies) and economic point of view.		
Common approaches to the life-cycle analysis and to quantify the system-level benefits of the proposed solutions.		

Following the analysis of the portfolio composition, the following categories were drawn up:

- Technological Focus: Group projects based on their core technology or approach, such as photoelectrochemical, photochemical, chemical, thermal, electrochemical, biological and hybrid.
- Target Application or Product: Identify projects based on the end-product they aim to produce or the application they target, such as bio-batteries or renewable chemicals.

2.3

OBJECTIVES AND CHALLENGES

The portfolio has the objective to position Europe strategically at the forefront of sustainable technologies for CO_2 and N-compounds management/valorisation. The overarching portfolio goal is hence to contribute to identifying and accelerating the development of the most promising CO_2 and N-compounds management/valorisation technologies to address the challenges of climate change, global warming, and water/soil pollution in line with the European Green Deal targets. The portfolio activities will stimulate collaboration among the projects and the networking within the innovation ecosystem to enhance the development of the EU's technological autonomy in this field.

The portfolio's activities target three main areas: **technologies**, **regulations**, and **innovation journey**. In addition, there is a layer of portfolio management and communication activities to facilitate the collaboration between the projects and to promote the achievements of the portfolio. The technological area is addressed by leveraging synergies between projects to speed up the technological progress, through the sharing of knowledge, research methodologies, multidisciplinary approaches, simulation tools and laboratory equipment. This dimension also includes the techno-economic and environmental comparison of the different technologies proposed to produce high-level policy feedback on the optimal routes from a system-level perspective. The regulatory dimension is also particularly relevant, considering that most of the proposed solutions need public support and proper market mechanisms to be economically competitive before being fully scaled-up, including reliable and effective standardization and certification mechanisms. The grouping of projects helps to streamline communication on their specific requirements to catalyse and foster innovation, and to ensure their visibility in front of stakeholders, policymakers, regulatory and policy bodies. The creation of the portfolio is a step towards achieving the critical mass necessary to eventually achieve policy changes/updates and to enable the technologies' development. Finally, the projects work together to improve their exploitation strategies (how to make a business out of their results), and nurture entrepreneurial mindsets.

The below sections provide an overview of the common hurdles for projects within the three target areas, in the field of CO_2 and N-compounds management and valorisation.

2.3.1
TECHNOLOGIES

The main challenge of the projects is to develop a technology that will convert the inputs from different waste streams into added-value products in an economically and environmentally sustainable process. Technological challenges that the projects will have to overcome include:

Purity of the source/inputs/feedstock

A. The CO_2 and N-compounds coming from flue gas and wastewater as sources for the conversion technologies will be in dilute form and mixed with many impurities of various types. A certain level of gas purity is required in conversion processes, where the yield depends on the CO_2/N-compounds concentration as well as the type and quantity of impurities present. The **exact quantification of purity** and the chemical composition of the whole feedstock mixtures of such diluted forms, and consequently **which technology will be used/developed to purify**, is one of the challenges that the projects will have to overcome. The streamlined functioning of the units for capture, separation, purification, and concentration of both CO_2 and N-compounds will be extremely important for the overall Life Cycle Analysis (LCA). Consequently, additional gas purification systems may be integrated to ensure durable separation performance. This leads to an increase in the cost of the CO_2 "overall" capture process. Therefore, **tolerance to contaminants** must be carefully addressed when implementing new carbon capture technologies.

Capture

A. Carbon capture from flue gas poses several challenges due to the **large gas volume and the low CO_2 concentration** in these streams (typically 5–20%). The latter, combined with the fact that these streams are also close to the atmospheric pressure, presents a significant hurdle. This is a thermodynamic constraint that hampers the efficiency and economic viability of such technologies. **The challenges are even more pronounced for direct air capture (DAC)**, where CO_2 concentration is 3 – 4 orders of magnitude lower than in flue gas or other CO_2-emitting sources. Another issue, closely tied to the thermodynamic containments, is the **high energy requirement** of the of the CO_2 separation and purification process. Current benchmark technologies such as amine scrubbing suffer from an energy penalty for regeneration along with the production of toxic wastes. Therefore, the challenge lies in developing a suitable technology that requires low energy input (LOW OPEX) and has enhanced performance in terms of capture efficiency and purity of the final products. This challenge necessitates the discovery of novel high-performing materials such as metal-organic frameworks (MOFs), polymers of intrinsic microporosity (PIMs), or membranes able to capture large amounts of CO_2 for extended time periods under mild pressure, but at the same time, able to release it under the correct stimuli and with a low energy cost.

B. An additional issue is characterisation and **standardization of capturing performance**. Currently, it is very difficult to compare the different capturing technologies due to the broad range of testing conditions, even in the same class of materials/technology. Moreover, capturing materials/technologies are usually tested with pure gas or ideal simulated mixtures and not in the presence of industrial flue gas that, as shown in Table 6, will be the most common source of CO_2.

C. Lastly, a technological challenge in CO_2 capture involves **scalability**, particularly concerning the availability of novel materials at an affordable price. The critical factor for the industrial implementation of newly developed technologies lies in the design of non-critical raw materials that are easily synthesizable on a large scale.

D. Some of the projects within this portfolio, such as SUPERVAL and DAM4CO_2, aims to address all these challenges, developing novel high-performing, stable, non-critical and scalable materials for CO_2 capture.

Conversion

E. In the realm of **electrochemical conversion** (e.g., ICONIC, CONFETI, ECOMO, SUPERVAL), the primary challenges revolve around achieving high current densities for enhanced conversion yields and superior product selectivity. This is particularly crucial in the case of CO_2 reduction, where a plethora of products (such as formate for SUPERVAL) can be generated, and selectivity is influenced by the current density. An additional concern involves critical raw elements, often resulting in suboptimal durability and performance. Furthermore, the design of compact electrochemical cells (with minimal gaps) is essential to reduce system resistance and increase current density. As a result, both electrolyzer and co-electrolyzer systems entail the optimization of multiple variables (faradaic efficiency, selectivity, stability, and overall yield) before progressing to prototype development. Achieving this objective may involve the utilization of simulation models for a priori performance prediction.

F. Regarding **photochemical conversion** (e.g., SUPERVAL, DAM4CO_2, CONFETI) the main issue is the need for very large light-exposed areas or radically improved catalyst performance to achieve conversions of practical interest, for the projects to be competitive with benchmark industrial methods (e.g. the Haber-Bosch process for NH_3 production). For example, SUPERVAL is proposing a photo-upgrading pathway for the conversion of N-compounds of flue gas streams into NH_3. In particular the project targets photo-fixation of N_2 and NO_x. The complexity of the N_2 fixation is intrinsic with the reaction, requiring activation and dissociation of a highly stable molecule showing very sluggish reaction kinetics, as well as H2 splitting to hydride. In the case of NO_x, the challenges are mostly related to the very low concentration and heterogeneity of the source. Instead, DAM4CO_2 is proposing photochemical conversion of CO_2 first to CO and then into C_4^+ as final products in a single device, where CO_2 capture is also performed simultaneously.

G. Challenges in **thermochemical conversion** of biomass relate to significant variations in feedstock composition and material structure, the complex pathways of chemical reactions, and transport mechanisms. For example, differences in organic and inorganic content can profoundly affect the process. These challenges make generic process development challenging. Challenges for the multi-step process of the MINICOR project are to develop a system achieving stable and efficient generation of biooil and syngas combined with the formation of biochar with properties for uptake and controlled release mechanisms of nitrogen compounds.

H. Numerous projects within the portfolio are pioneering a **hybrid approach** to carbon and nitrogen management. These initiatives must tackle both individual scientific and technological challenges mentioned earlier, as well as issues associated with integrating diverse technologies. For instance, SUPERVAL aims to validate a modular technology at the lab scale, that is capable of capturing and valorizing carbon and nitrogen components from flue gas streams using sunlight as the primary energy source and water as a hydrogen source. Specifically, this project envisions: i) photovoltaic-driven electrochemical conversion of CO_2 and water into formate and green hydrogen, ii) photo-assisted fixation of N-compounds (N_2, NO_x) into NH_3 using the green hydrogen produced, and iii) the separation and purification of the different gas components. Electrochemical processes hold high interest for the EU's green transition due to their compatibility with intermittent light sources. However, a critical issue in photo-electrochemical conversion is aligning solar power with electrocatalytic processes, considering the stress induced by intermittent irradiation, impacting process selectivity. ECOMO combines electrochemical and thermal enzyme/microbial conversion technologies. CO_2 is electrochemically transformed to CO using CO_2-to-CO converting enzymes in the first step. This will be followed by thermal conversion approaches to combine CO and ammonia/nitrates through two more steps using biotechnology and metabolic engineering. Interfacing these electrochemical and thermal components for maximum conversion efficiency of CO 2 and NH_3 to amines is one of the scientific challenges that ECOMO seeks to achieve. CONFETI combines electrochemical/ photochemical/microbial technologies. One of the issues in this case is to interface renewable electricity with biotechnology and metabolic engineering efficiently. Moreover, another relevant technological challenge addressed within this project is to produce and deliver urea (on site and on demand) by combining renewable energy sources, such as microbial fuel cells and sunlight technologies, while restoring the initial conditions of fields and enhancing soil health. This will be highly relevant in the field of the electro and photochemical conversion of CO_2 and N-compounds into fertilizers.

2.3.2 REGULATIONS/POLICIES

In the last years, the European Union has made tremendous progress in the field of environmental policies. However, the lack of regulations in specific areas relevant for the portfolio is a major challenge for the transformation of these technologies into market-ready products. In this section, the regulatory/policy framework relevant for the portfolio is considered and the related challenges are identified. In particular, the Multidisciplinarity of the portfolio projects is reflected in the diversity of the regulations/policies involved.

A. The primary goal of policies associated with the EU-wide transition to a green economy and the Farm-to-fork strategy (F2F) is to achieve a significant reduction in the overall use and risk of chemical pesticides and fertilizers. The EU's F2F strategy is considered to facilitate the adoption of the technologies and solutions developed within the portfolio as they substantially reduce or alleviate the need for the use of pesticides and fertilizers while effectively managing nutrients and having minimal impact on the environment. Furthermore, the EU's strategy to guarantee the availability and affordability of fertilizers aims to promote the production of environmentally friendly fertilizers by supporting investments in clean hydrogen and biomethane for ammonia production. Within this framework, specific policies supporting the green production of fertilizers and NH_3 from innovative technologies, such as those developed within the portfolio (e.g., SUPERVAL, CONFETI, ICONIC), would be highly significant, as they would foster a diversified and more effective approach to address this issue. Additionally, many solutions developed within the portfolio facilitate in-situ fertilizer production, which is strategically important for ensuring EU security of supply and avoid critical import dependencies.

B. The Directives promoting the use of energy from renewable sources as the Directive (EU) 2018/2001 will directly affect technologies, managing both CO_2 and N-compounds, developed within the portfolio as they require renewable energy inputs.

C. Policies funding the development of technology testing facilities/platforms: The accelerated development of CO_2 and N-compounds management and valorisation technologies will also depend on the funding of testing facilities/platforms where new technologies can be scaled up. Small infrastructures are already available in different countries, but for new technologies to reach the market, larger-scale lab/pilot facilities are needed. For example, an EU lab that enables tests at large scale and in environments close to industrial needs is missing for testing and standardization of technologies for carbon capture and reduction of nitrate emissions.

D. Regulations concerning the use of a genetically modified organism (GMO) to produce food for human consumption are more relevant to the goals of the HYDROCOW project as they affect its potential commercialization objectives. Despite the evidence that humans have manipulated the genes of crops and animals via selective breeding since prehistoric times and genetic engineering technology has been practiced for over 50 years, the European Union has one of the strictest regulatory landscapes with respect to the use of GMOs. There are a number of different Regulations and Directives related to i) the use of genetically modified food and feed ((EC) 1829/2003), ii) contained use of micro-organisms (2009/41/EC), and iii) the deliberate release of GMOs into the environment (2001/18/EC, 2018/350/EU) and Guidelines set by the European Food Safety Authority (EFSA) GMO Panel (EFSA GMO Panel

2010, EFSA GMO Panel 2011a, EFSA GMO Panel 2011b, EFSA GMO Panel 2017), FEEDAP Panel (EFSA FEEDAP Panel 2018) and CEP Panel (EFSA CEP Panel 2019).

Policies/regulations mainly related to nitrogen

E. **Policy measures related to atmospheric reactive nitrogen** (Nr): a relevant grouping of EU directives deals with emission of GHG and hazardous reactive nitrogen compounds such as NO_x and NH_3 into the atmosphere (2008/50/EC, 2016/2284, 2010/75/EU). These policies have been introduced with the aim of preventing and controlling atmospheric emissions of Nr also by establishing national emission ceilings. Moreover, nowadays NO_x reduction occurs almost entirely through the conversion into N_2, losing a valuable resource and increasing, as a secondary effect, nitrogen and energy losses as estimated by experts (Nitrogen Opportunities for Agriculture, Food & Environment UNECE Guidance Document on Integrated Sustainable Nitrogen Management). This guideline document is expected to shape future EU policies and beyond. Some of the projects within this portfolio (SUPERVAL, CONFETI) address atmospheric Nr challenges.

For instance, the specific objective of SUPERVAL is directly aimed at cutting NO_x emissions from industrial combustion sources and converting them into a valuable product (NH_3) in a sustainable way. The current stringent rules in force regarding Nr atmospheric reduction, as well as the forecast of their tightening, will thus boost the interest in the dedicated technologies developed within this portfolio.

F. The water framework directive encompasses all EU legislation aimed at safeguarding inland surface waters, transitional waters, coastal waters, and groundwater. This directive also deals with wastewater treatment and sanitation included parameters that encompass nutrient balancing, and negative energy offsetting, including biological solutions. Projects like Mi-Hy and CONFETI which use Bio-electrochemical systems (i.e., Microbial Fuel Cells), would act as an enabler for commercial (and manufacturing) entities to show more interest and even invest in biological solutions. This would offload pressures on centralised wastewater processing plants and enable more distributed forms of processing that are turned into high(er) value products e.g. bioelectricity, cleaned water, and biomass.

G. Regulations on the **recovery and revalorisation of nitrates from bodies of water**, specially from agriculture runoffs, would facilitate the commercialisation of technologies developed within the portfolio that will have wastewater or seawater as an input. Projects like ICONIC aim to develop an electrochemical technology that can convert nitrates and carbonates in seawater into urea, closing the nitrogen loop and avoiding eutrophication. Regarding emissions, the most recent and solid regulation is the (91/676/EEC) which regulates water quality monitoring and the identification of areas at risk of pollution.

H. **Policies are required to prevent further soil degradation**: A challenge faced by projects that focus on fertilizer as their end-product (e.g., Mi-Hy, CONFETI, ICONIC) is the existence of low-cost nitrate and phosphorus fertilizers on the markets that leach into the soil, contaminate ground water, and facilitate eutrophication. Governments are now acting with legislation against these fertilisers. The portfolio will enable biological solutions that can produce environmentally sustainable, balanced, available locally where needed, naturally derived sources of nutrients for plant growth. The fast market entry of such solutions will depend on valorising the circular and bio economy, and on policies preventing further soil degradation.

I. **Nitrogen management based on biochar (MINICOR)** will be influenced by standardization and legislation for this category of materials. Voluntary biochar product standards have emerged via initiatives such as the biochar standard of the International Biochar Initiative (IBI-BS) and the European Biochar Certificate. In addition, national legislation on biochar utilization in some European countries, that requires the nitrogen content of biochar to be declared and that limits for nitrogen addition in so-called Nitrate Vulnerable Zones, need to be considered. The EU regulations on fertilisers (EU2019/1009) address biochar technology and recommends that biochar-based products should be able to access the market when the manufacturing process has been analysed and process requirements have been established.

Policies/regulations mainly relating to CO_2

J. EU-wide land use policies (EU LULUCF) are pivotal components of the EU's climate strategy, aiming to regulate greenhouse gas (GHG) emissions and removals associated with land use, forestry, and land-use change activities. This regulation affects how the portfolio projects will monitor, report, and verify emissions and removals of GHGs from the land sector to ensure it contributes to the EU's climate objectives. The EU LULUCF is foreseen to facilitate the adoption of the technologies and solutions developed within the portfolio, as they will reduce land use needs.

K. Regulations concerning **CO_2 emission allowances** such as the **EU Emissions Trading System** will drastically affect technologies developed within this portfolio, strongly conditioning their adoption at an industrial scale and the introduction into the market. In addition, the regulations should include circularity (CO_2 capture and reuse) and/or as an exemption penalties for non-circular strategies. A specific regulatory framework should strongly incentivize the use of renewable chemicals/fuels. This would drastically boost the renewable fuel market and prevent the build-up of GHGs in the atmosphere. In the realm of carbon capture and utilization, the EU is already supporting actions and technologies as those developed within this portfolio, for boosting the utilization of sustainable carbon as a resource across various industrial sectors, encompassing chemicals, advanced synthetic fuels, polymers, and minerals. Additionally, it will formulate a comprehensive framework to both track and facilitate the implementation of innovative and sustainable carbon capture and utilization applications.

L. The Carbon Removal Certification Framework (CRCF) aims at creating a unified system to define and certificate carbon dioxide removal (CDR). The CRCF categorizes CDR and encompasses comprehensive methodologies delineating the certification processes for each CDR approach. The CRCF is poised to influence climate policies within both the EU and its affiliated national governments, with significant anticipated ramifications for the voluntary carbon market. The CRCF should be taken into account because it is expected to boost the CO_2 removal market, thereby affecting the competitiveness of technologies developed within this portfolio, primarily dedicated to converting CO_2 into valuable products rather than long-term storage. As mentioned in the previous point, these technologies should be further incentivized with specific regulations with the aim of promoting CO_2 emissions reduction by circular economy.

M. Although projects of this portfolio are aimed at converting CO_2 into valuable products, regulations regarding carbon dioxide storage (Directive 2009/31/EC) could also affect some of the projects if storage is needed for a share of the capture CO_2. Considering the actual environmental EU policy, the introduction of a unique regulatory framework that encompasses both carbon capture and utilization would be highly beneficial.

2.3.3
INNOVATION JOURNEY

The main challenges influencing the portfolio's innovation journey revolve around visibility, investment, and poor information flow. More concretely, the challenges that the portfolio seeks to overcome to foster their innovations to the market include:

A. Stronger collaboration between the different value chain actors/stakeholders (industry, end users, etc.), that could accelerate the innovation journey of the portfolio technologies. For example, without **adequate information** on the different impurities present in the flue gas and wastewater from industries, research labs are forced to rely on testing their CO_2 and N-compounds management and valorisation concepts using pure inputs, such as pure CO_2 and pure NH_3. They would benefit from receiving transparent information from the industries (i.e., on flue gas composition) to develop such technologies starting from real inputs.

B. **Acceleration of the market positioning** of sustainable innovations that would substitute efficient and economically profitable, but not environmentally sustainable, industrial solutions, such as the Haber-Bosch process or petrochemicals; new business models will have to be designed and developed for this purpose.

C. There is a need to identify how to **further stimulate and de-risk private investments in new technologies** that are not yet validated, especially in conservative sectors such as agriculture. Quantitative benchmark parameters, such as Key Performance Indicators (KPIs), may not exist for such new technologies at the start. In such situations a mechanism needs to be developed to create a certain level of trust and understanding between the academic research groups, funding agencies, stakeholders, and policymakers.

D. There is a need to **facilitate the discussion between different policymakers** (local, national and EU). This may allow the standardisation of policies on industrials waste effluents (i.e., flue gas, wastewater) treatments to stimulate the pilot-scale testing of CO_2 and N-compounds management and valorisation technologies. This would be important in de-centralising the production of nitrates as fertilisers and establish locally available nutrients from local waste streams, potentially on demand at Sites of need, which would prevent surpluses, thereby reducing run-off and increasing the quality of soil and water.

2.4
COLLABORATION BETWEEN PROJECTS

The portfolio projects have explored potential collaborations (1-to-1, 1-to-many) during the portfolio kick-off meeting in November 2023 and in multiple subsequent discussions between the different working groups. The collaborations are intended to facilitate the projects' innovation journeys and address the common challenges of the portfolio. The table below summarizes the planned activities in different focus areas. Each number represents a potential cooperation between projects, further elaborated in the text below.

Table 3. Portfolio collaboration

	Mi-Hy	CONFETI	SUPERVAL	DAM4CO2	HYDROCOW	ICONIC	ECOMO	MINICOR
Mi-Hy		12 / 21	9	7,9		1 / 18		18
CONFETI	12 / 21		9 / 16,17	4,9 / 16,17	13 / 1	20	1	14 / 19
SUPERVAL	9	9 / 16,17		6 / 16,17	10	15	10 / 11	19
DAM4CO2	7,9	4,9 / 16,17	6 / 16,17		5,9		3,9	8 / 19
HYDROCOW		13 / 1	10	5,9		1	1 / 11	
ICONIC	1 / 18	20	15		1		2	18
ECOMO		1	10 / 11	3,9	1 / 11	2		
MINICOR	18	14 / 19	19	8 / 19		18		

SHARED INPUTS
CAPTURE AND PURITY OF SOURCES/INPUTS/FEEDSTOCK
CONVERSION
MATERIALS
EQUIPMENT
MULTIPLE COLLABORATION OPPORTUNITIES

In addition, appropriate laboratory resources and characterization methodologies both potentially available for sharing and potentially desired techniques are compiled within the portfolio documentation.

Shared inputs

1. **CONFETI**, **ECOMO** and **HYDROCOW** plan to use a source of N-compounds (such as ammonia or nitrates) from soil or water as the N-input. **ECOMO** plans to use NH_3 from wastewater (from local sewage plants), which will be converted to nitrates before feeding the nitrates to bacteria for conversion into the final product diamines. Since nitrates are the common point of intersection, **HYDROCOW**, **ECOMO** and **CONFETI** can benefit from each other's approaches and methods to capture and purify these sources, keeping Intellectual Property Rights (IPR) in place. Also, the urea produced in **ICONIC** could serve as feedstock for projects **HYDROCOW** and **Mi-Hy**.

Capture and purification of sources/inputs/feedstock

2. Both **ICONIC** and **ECOMO** will address the challenges of dilute sources of N (from wastewater). They will collaborate, respecting their own IPR, on: a) the level of purity of the N-input from the N source, b) pre-treatment and concentration methods of the N-input compounds like ammonia and nitrates from the N-source, c) different technologies developed and employed to connect and combine C- and N-sources, and d) technologies dealing with the C- and N-sources separately to achieve the desired products.

3. Both **DAM4CO$_2$** and **ECOMO** are addressing the challenge of purity of CO_2 sources. **DAM4CO$_2$** will develop mixed-matrix membranes for this purpose, which is not the direct objective of **ECOMO**, but could be a beneficial cross-link between the overall technology developed in **DAM4CO$_2$** and **ECOMO**.

4. Flue gas treatment is part of both **CONFETI** and **DAM4CO$_2$**. Even though using different membrane materials, both projects will use membranes for CO_2 capture. Therefore, membrane preparation and characterization techniques can be a point of common interest.

5. **HYDROCOW** needs purified flue gas to feed its system, and this is one of the main scopes in **DAM4CO$_2$**. Thus, the capture technology of **DAM4CO$_2$** and the valorization technology of **HYDROCOW** could be coupled.

6. Both **SUPERVAL** and **DAM4CO$_2$** incorporate CO_2 capture and purification from flue gas. Both use MOFs in their capture system, as powder in **SUPERVAL** and as Mixed Matrix Membranes in **DAM4CO$_2$**. Thus, possible exchanges of preparation and characterization protocols can be exploited.

7. **Mi-Hy** uses atmospheric CO_2 for its hydroponics systems. **SUPERVAL** or **DAM4CO$_2$** technology could be used to concentrate the CO_2 in the streams used to feed the hydroponics plants.

8. **DAM4CO$_2$** will focus on the purification and concentration of CO_2, so this can be of general interest, e.g. for the reforming process in **MINICOR**, since the technology is highly scalable.

9. One of the primary technological challenges of **SUPERVAL** is addressing gas purity. **SUPERVAL** technology could thus be applied to the projects/applications where a specific gas purity is required e.g. **Mi-Hy**, **CONFETI**.

10. **SUPERVAL** incorporates CO_2 capture from flue gas and its purification in its technology. **ECOMO** and **SUPERVAL** can benefit from each other in this context since **ECOMO** also aims to use CO_2 from flue gas towards the end of the project to validate its technology in local commercial settings. With all IPR and NDA in place, the two projects foresee a collaboration and amalgamation of their technologies for an integrated approach towards CO_2 capture, purification, conversion, and valorisation.

Conversion

11. Both **HYDROCOW** and **ECOMO** will use microbial gas fermentation to convert CO_2 and nitrogen sources. Therefore, an exchange between the two to compare and integrate the technologies developed might be beneficial in terms of policymaking and stakeholder mapping.

12. **Mi-Hy** and **CONFETI** propose the use of microbial fuel cells and bio-electrochemical systems for energy production. The projects are exploring ways of collaboration in the electrochemical (design of the cell, materials, etc.) and biological parts (type of bacteria, ways of immobilization, etc.).

13. **HYDROCOW** is proposing the modification of microorganisms to improve the production processes. Some of these technologies are interesting to the **CONFETI** partners to improve the performance of the microbial fuel cells.

14. The **MINICOR** project proposes the pyrolytic transformation of CO_2 to carbon, which may be used as a carbon electrode in the transformation of CO_2 to urea, as proposed by **CONFETI**. This collaboration will be investigated in the portfolio.

Materials

15. Knowledge on advanced materials could be shared between **ICONIC** and **SUPERVAL** (e.g., CRM-free catalysts for anodes).

16. Both **SUPERVAL**, **DAM4CO$_2$** and **CONFETI** will use Cu-based catalysts for CO_2 valorisation. **SUPERVAL** and **DAM4CO$_2$** use MOFs in their capture technologies.

17. **CONFETI** consortium could use the photovoltaic panel developed within **SUPERVAL**. Moreover, also in this case, both projects could share knowledge on the design of photochemical reactors, which is a crucial point in **DAM4CO$_2$** as well.

18. **MINICOR**'s utilization of porous biochar material is a common topic of interest with other projects, e.g., **Mi-Hy**. The potential application of biochar for wastewater treatment can be compared with the concept of **ICONIC**.

Equipment

19. The **MINICOR** partners have extensive laboratory facilities for thermochemical conversion at different scales that could provide opportunities for investigating concepts for CO_2 capture, e.g., for projects **CONFETI**, **SUPERVAL**, and **DAM4CO$_2$**.

Multiple collaboration opportunities

20. By sharing a common technology (electrochemical conversion) and the same target product (urea), **ICONIC** and **CONFETI** can share knowledge, among others, on catalysts, system design, and urea purity.

21. A range of potential synergies exist between **Mi-Hy** and **CONFETI** that will be explored including: i) using bio/electrochemistry to convert CO_2 and N_2 directly from air or flue gases without the use of critical raw materials and using renewable energy sources; ii) establishing a circular and renewable carbon and nitrogen economy using microbes (looking for synergies within species/strains) and light (sun/LED); iii) biosynthesis e.g. fertiliser, biomolecules (e.g. 2,3, BDO); iv) development of BES hardware to promote biobased biosynthesis processes;

v) valorising and promoting the efficiency of available resources, the sustainability of the agricultural sector, the preservation of the environment and the safety and quality of products.

22. The following projects share a common target application category that is Bioengineering and Sustainable Agriculture Solutions. This might help with collaborating on commercialization strategy.

- **HYDROCOW**: Engineering hydrogen-oxidizing bacteria for food-grade protein production from CO_2 and N-compounds.
- **Mi Hy**: Microbial hydroponics for optimized N-compounds use in agriculture.
- **CONFETI**: Fertilizer production using electrolysis powered by soil fuel cell technology and sunlight photocatalysis.
- **ICONIC**: Electrochemical urea production from waste streams and seawater relevant to agriculture.
- **MINICOR**: Converting biomass residuals into N-enriched biochar as an agriculture fertilizer.
- **ECOMO**: Transforming and combining CO_2 and ammonia into valuable chemical compounds.

2.5

GOVERNANCE

The portfolio is governed on two levels: strategic steering and operational steering. The two levels are connected through the project coordinators (see Figure 2).

The high-level strategic steering of the portfolio is done by the EIC Programme Managers in close collaboration with:

- the **Project Officers**;
- the **8 project coordinators**;
- the **Advisory Expert Group**, composed of external experts selected by the EISMEA on their expertise and ability to contribute to steering the portfolio with independent and impartial advice. All the experts have signed a Non-disclosure Agreement (NDA) with the EIC and, hence, are entitled to discuss the detailed characteristics of each project. The experts can propose and conduct activities beneficial to the whole portfolio;

Governance of the portfolio

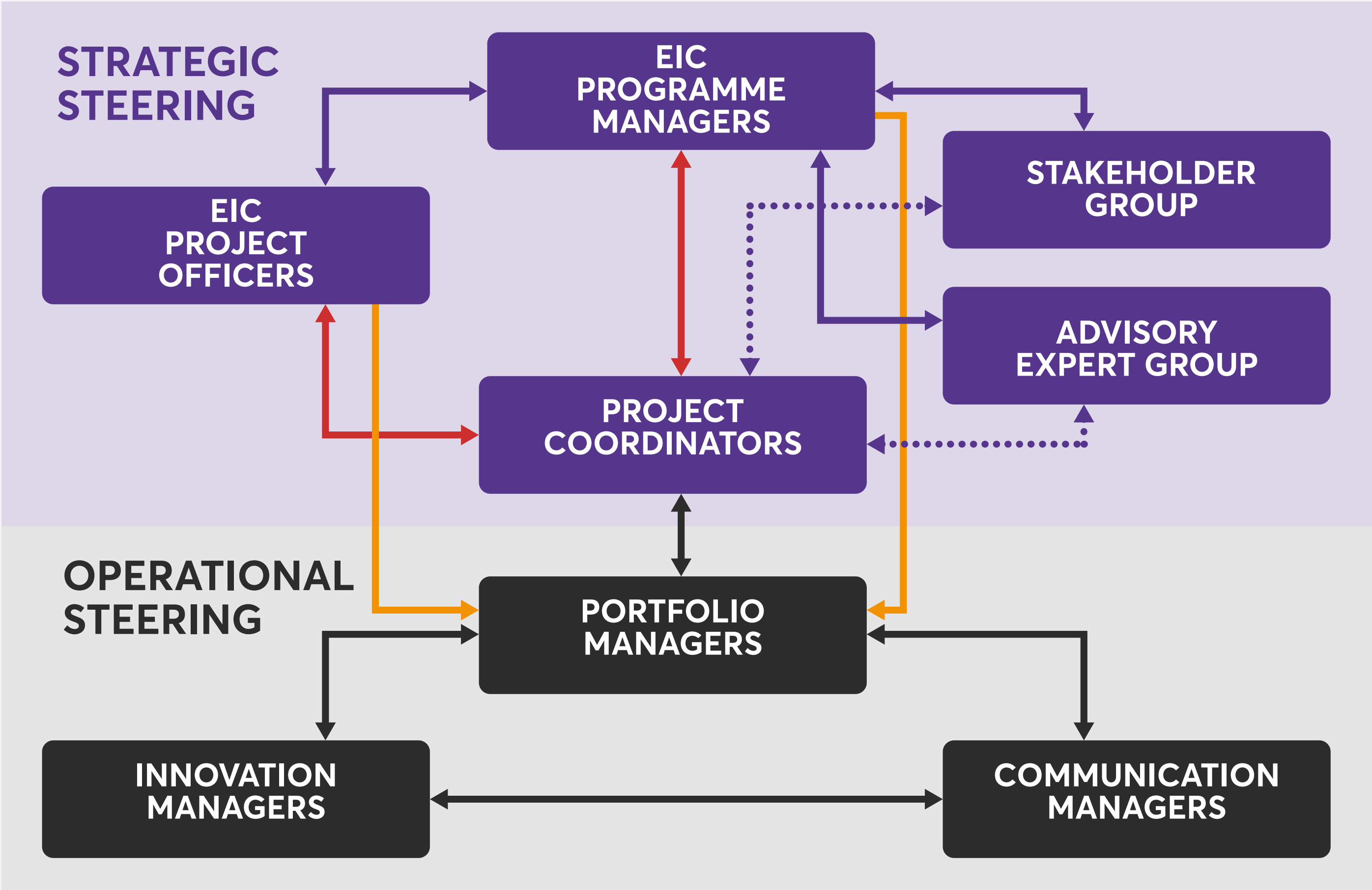


Figure 2. Interactions among the key actors of the portfolio.

- The **Stakeholder Group**, composed of global value chain actors such as industry representatives, potential end-users, investors as well as policymakers. This group serves to foster portfolio exploitation activities through the exchange and engagement of industrial stakeholders belonging to the CO_2 and N value chains. The members of this group are called stakeholders. They provide non-binding strategic advice to the portfolio, or to a project. The stakeholders agreed to become part of the Stakeholder Group on a voluntary basis. There is no requirement on invested time and commitment, nor is there any obligation to share any data between the involved parties. Stakeholders are not allowed to ask the EIC or any involved party for financial remuneration; on the other hand, the EIC and the portfolio projects understand that the commitment by the stakeholders is purely voluntarily and upon the stakeholders' decision and willingness to engage. Portfolio projects are invited to suggest stakeholders to the PMs. There is neither a minimum nor a maximum number of stakeholders.

  The stakeholder group meets virtually for the first time when at least three board members have assumed their role. The PMs will present the portfolio projects to the stakeholder group. During this meeting, the stakeholders exchange their contact details, and further interaction is upon their initiative. The stakeholders are encouraged to proactively reach out to the projects in the portfolio, to advise them in their area of expertise and to update fellow stakeholder group members. They are likewise encouraged to exchange regularly with the PMs. Finally, projects are encouraged by EIC to reach out to stakeholder board members as well.

On the **operational side**, each project was asked to nominate specific managers for each of the **three activity pillars** to ensure targeted workflows within the portfolio and a clear hierarchy within the project consortia. These managers and their specific roles are:

- **Innovation Managers**, who oversee the exploitation strategies and elaborate the **exploitation plan** (this includes also the IPR strategy); they also identify the market potentials, manage the stakeholder's assessment, stimulate business development activities within the portfolio and manage the governance of the portfolio. They are also in charge of the identification of synergies, shared components, and collaboration opportunities with one or more projects and of the assessment of the competitiveness of the proposed technologies for different applications.

- **Portfolio Managers**, who oversee portfolio management and project governance activities, including the identification and establishment of synergies, shared components and collaboration opportunities with one or more portfolio projects. Also, they assess the competitiveness of the proposed technologies for different applications and participate in data collection for monitoring the technology development.

- **Communication managers**, who oversee the implementation of portfolio dissemination and exploitation activities. They are in charge of the elaboration of a joint communication strategy, including a common database for events on an online platform, communication activities and a shared database of scientific instruments.

Table 4. Allocation of the portfolio roles

PROJECT	PROJECT CORDINATOR	PORTFOLIO MANAGER	INNOVATION MANAGER	COMMUNICATION MANAGER
Mi-Hy	Rachel Armstrong	Rachel Armstrong	Ioannis Ieropoulos	Markus Schmidt
CONFETI	Gonzalo Guirado	Xavier Muñoz-Berbel	Pablo Vidarte	Beatriz De La Rica & Virginia Mata Marcano
SUPERVAL	Jose Ramón Galan-Mascaros	Jose Ramón Galan-Mascaros	Stefano Giancola	Arnau Jordà
DAM4CO_2	Alessio Fuoco	Bárbara Llobell	Johannes Carolus Jansen	Mireia Buaki-Sogó & Elisa Esposito
HYDROCOW	Arttu Luukanen	Juha-Pekka Pitkänen	Susanna Mäkinen	Senni Lehtonen
ICONIC	Pelayo Garcia de Arquer	Luis Guillermo Gerling	Luis Guillermo Gerling	Marta Martin
ECOMO	Nicolas Plumeré	Hemlata Agarwala	Melanie Iwanow	Melanie Iwanow
MINICOR	Christian Brackmann	Hesameddin Fatehi	Raffaele Ragucci	Sven-Inge Möller

3. PORTFOLIO IMPLEMENTATION

3.1 PORTFOLIO WORK PACKAGE

The work package relates to portfolio activities that are included in each project's signed grant agreement and includes the following tasks.

Table 5. Tasks included in the portfolio work package

#	TASK	RESPONSIBLE
Task 1	**Portfolio management and project governance** • Regular meetings and exchanges among the portfolio projects. • Set up an operational internal governance.	Portfolio Manager
Task 2	**Cross-catalyse innovation within the portfolio and address shared challenges** • Collaborations with other projects of the portfolio on technological developments and know-how generated by the beneficiaries.	Innovation Manager
Task 3	**Stimulate innovation opportunities/actions** • Creating opportunities to nurture innovations arising from the project. • Performing actions aimed at strengthening the EU research community on CO_2 and N-compounds management and valorisation: o Mapping, categorization of all the stakeholders and potentially the establishment of key partnership(s); o Exchange of the market research analysis results among the portfolio projects; o Continuous engagement with strategic partners and stakeholders.	Innovation Manager
Task 4	**Implementation of portfolio dissemination and exploitation activities** • Designing and participating in outreach events at the portfolio level.	Communication Manager
Task 5	**Assessment of the competitiveness of the proposed technologies for different applications** • Identification of common metrics to measure KPI in terms of techno-economic and environmental performances, comparison of key results to assess the relative competitiveness of the technology proposed. • Collaborating with the other projects in the portfolio to contribute to a common document on the key technical and non-technical factors that influence the adoption of the proposed technology in each final user segment.	Portfolio Manager

These tasks are realised through a series of concrete actions that were agreed upon during the Portfolio Kick-Off Meeting held in November 2023 and that will eventually be updated (see Annex C). Each activity has been assigned to a project to lead and coordinate. Additionally, there are three working groups, each consisting of at least eight members (one representative from each project):

- WG Coordinators
- WG Innovation and Portfolio Managers
- WG Communication Managers.

Each portfolio activity listed in Annex C is allocated to at least one of the members of the working groups.

3.2 DELIVERABLES

Annual report on portfolio activities:

The report will present the collaboration activities that have been carried out in each reporting period and contain relevant material (e.g. PowerPoint presentations, minutes of meetings, etc.). It also explains how the portfolio activities and the EIC proactive project management approach contribute to the achievement of the objectives and help the transition to market. This annual report is elaborated by the Communication Managers' group.

Joint technical report:

Contribution to a joint technical report with other projects in the portfolio on the key factors affecting the penetration of the proposed technologies in each market segment and the relative competitiveness of each solution in different end-user applications. This report includes the following three components:

- CO_2 and N-compounds value chain assessment.
- Materials selection and potential interactions for the use of non-critical raw materials;
- Techno-economic and LCA comparison of proposed technologies with common methodology.

Annex A Portfolio composition

The portfolio consists of a total of 51 partner organisations, representing 12 EU member states and 3 non-EU countries. A significant part of the participating organisations are universities or other higher education institutions, but research and technology organisations (RTOs) and private, for-profit entities are also represented. The portfolio includes 8 small or medium size enterprises (SMEs).

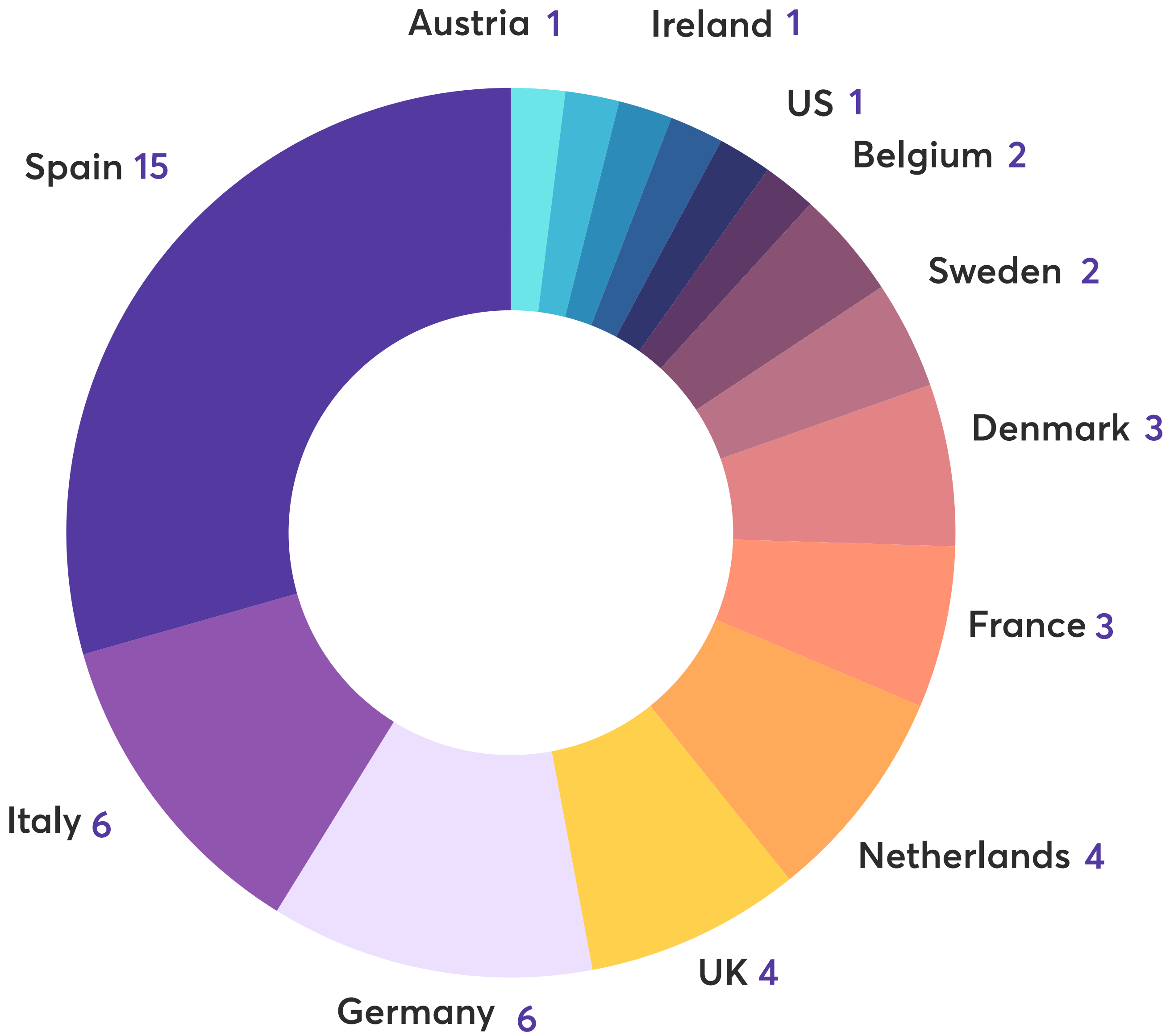


Figure 3. Number of portfolio partners per country

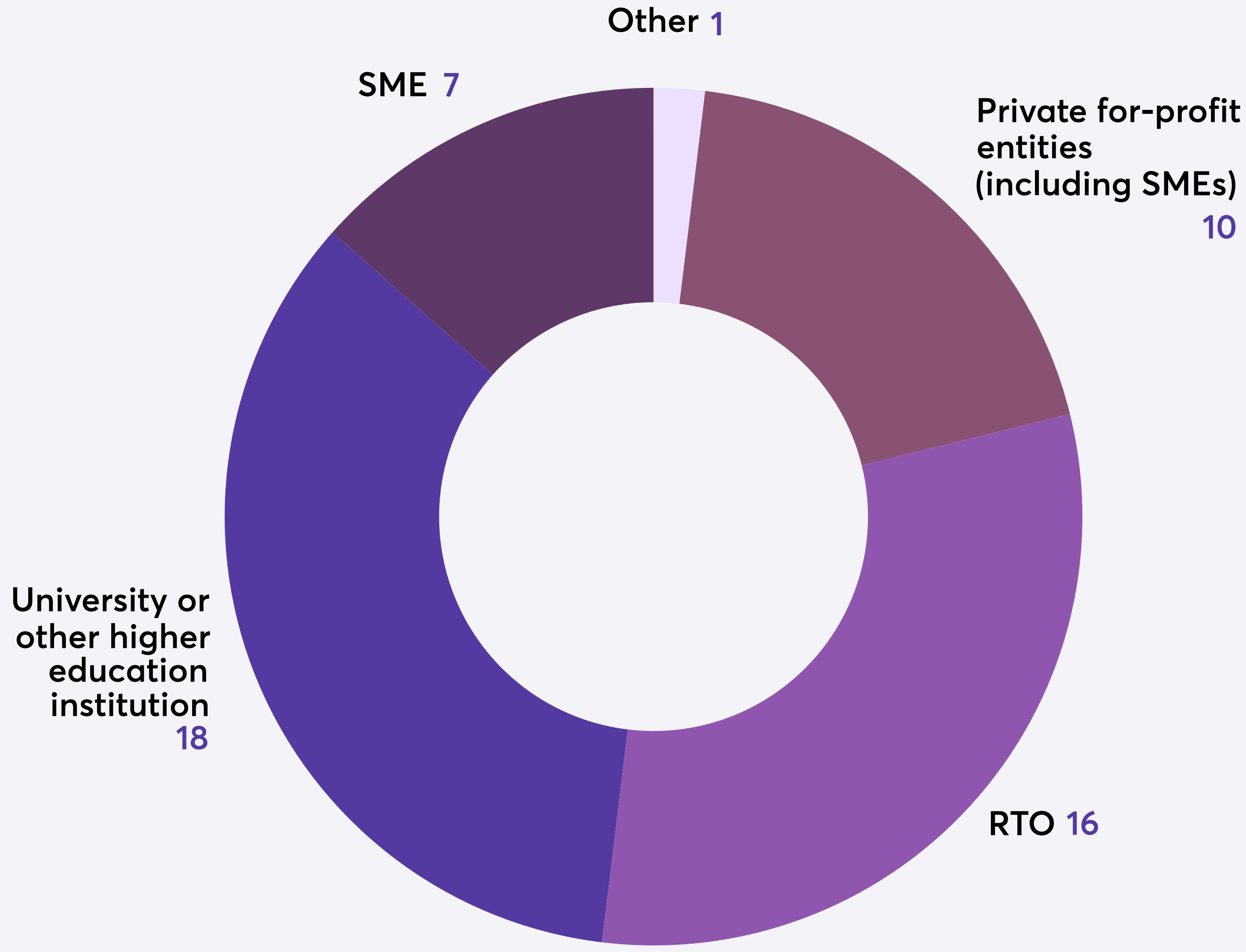


Figure 4. Number of portfolio partners per type of organisation

Table 6. Project technical details, CO_2

PROJECT ACRONYM/ TECHNOLOGICAL AREA	CO_2 SOURCES	C- COMPOUNDS AS A SOURCE/ INPUT	PURITY OF THE SOURCE/ INPUTS	REQUIRES PRE-TREATMENT OR PRE-CONCENTRATION (YES/NO)	CAPTURING MATERIAL	CONVERSION TECHNOLOGY/ TECHNOLOGICAL AREA	CATALYST	OTHER REACTANTS AND SOLVENTS USED	INTEGRATED CAPTURING CONVERSION (YES/NO)	FINAL PRODUCT/S	ESTIMATED END PRODUCTION QUANTITY AT POC LEVEL	FINAL USE (APPLICATION FIELD)
ECOMO / E	Flue gas	CO_2	>90%	Yes	Redox hydro-gels	Bioelectrochemistry and Biotechnological gas fermentation (E)	CO_2 to CO converting enzymes; acetogenic bacteria	N/Applicable	Yes	Acetate (intermediate for diamines)	20 g L^{-1}	Chemical industry; food industry in the form of vinegar,
CONFETI / E	Air/flue gases	CO_2	N/A	Yes	Ionic liquids; deep eutectic solvents; iono-gels	Electrochemical (E)	N-doped carbon materials	N/A	Yes	Urea	100mg/day	Agriculture (fertilizer)
HYDROCOW / D	Air (Carbon Capture (CC))	CO_2	>99%	Yes (see purity)	Currently COTS (Amine functionalized sorbents)	Microbial gas fermentation (D)	No catalyst (biological system)	Hydrogen	Yes	Food protein	~1 g/L/h (TBD)	Human foods
SUPERVAL / A	Flue gas	CO_2	To be determined	Yes, CO_2 capture and purification are part of the project	MOF	(photo)electrochemical (A)	Doped Cu	Water	Yes	Hydrogen and formate	TBD	Chemical industry, agriculture and energy
ICONIC / C	Seawater; agricultural pretreated wastewater runoffs	Bicarbonates. (HCO_3^-)	100-150 mg HCO_3^-/L (Bicarbonates in seawater)	TBD	No capturing material	Electrochemical (C)	To be determined, but CRM-free catalysts	Additives for pH control	No	Urea	TBD (mg/L)	Agriculture (fertilizer)
DAM4CO_2 / A	Flue gas / other CO_2 emission	CO_2	To be determined (depends on the conversion)	Yes (steps included in the project)	Mixed Matrix Membranes (polymers and MOFs)	Photochemical (A)	Cu and Ni based catalysts	H2, solvents for materials and membrane preparation	Yes	C_4^+	TBD	Transport (fuel) and chemical industry
Mi-Hy / D	Wastewater/	CO_2, CH_3COOH, C	No purification needed; used neat	No	Biofilm bacteria on porous electrodes	Bioelectrochemical Systems; plant uptake (D)	No catalyst (biological system)	N/A	Yes	Electricity; plant growth hydroponically; balanced fertilizer	TBD	Remote area utility; agriculture; possibly chemical industry
MINICOR / B	Flue gas, biomass residues	Pyrolysis oil, pyrolysis gas, CO_2	Minimal purification needed.	No	No special material.	Thermal conversion process (B)	No catalyst (initially, may be added as option)	N/A	No	Syngas, biochar (nitrogen-enriched)	TBD	Energy supply, possibly chemical industry (fuel)

Table 7. Project technical details, N-compounds

PROJECT ACRONYM/ TECHNOLOGICAL AREA	NITROGEN SOURCES	N- COMPOUNDS AS A SOURCE/ INPUT	PURITY OF THE SOURCE/ INPUTS	REQUIRES PRE-TREATMENT OR PRE-CONCENTRATION (YES/NO)	CAPTURING MATERIAL	CONVERSION TECHNOLOGY/ TECHNOLOGICAL AREA	CATALYST	OTHER REACTANTS AND SOLVENTS USED	INTEGRATED CAPTURING CONVERSION (YES/NO)	FINAL PRODUCT/S	ESTIMATED END PRODUCTION QUANTITY AT POC LEVEL	FINAL USE (APPLICATION FIELD)
ECOMO / E	Wastewater	Ammonia (NH_3/ Ammonium (NH_4^+);	To be determined (TBD)	Yes	N/A	Metabolic engineering of bacteria (E)	No catalyst. Bacteria will be used to do the transformation.	Acetate from the previous gas fermentation step	Yes	Diamines $[NH_2(CH_2)_xNH_2]$	$0.5\ mol_{diamine}\ mol_{acetate}^{-1}$ (C3) to $0.2\ mol_{diamine}\ mol_{acetate}^{-1}$ (C6)	Chemical industries, polymer industries which use diamines as building blocks for amine-containing polymers, biotechnology industries
CONFETI / E	Air/ flue gases/soil	N_2, NO_3-	N/A	Yes	Ionic liquids; deep eutectic solvents; ionogels	Electrochemical Photochemical (E)	N-doped carbon materials	N/A	Yes	Urea;	80-100 mg/day	Agriculture (fertilizer)
HYDROCOW / D	Ammonia water solution (10-20%)/ (Urea, nitrates to be studied)	NH_3, NO_3-	TBD	Yes	engineered Hydrogen oxidizing bacteria	Currently Haber-Bosch / Future microbial gas fermentation (D)	N/A	N/A	Yes	Food protein	1 g/L/h (TBD)	Human foods
SUPERVAL / A	Flue gas	N_2, NO, NO_2	TBD	Yes (N-compounds capture and purification are part of the project)	MOF and active carbon	Photocatalysis (A)	Transition metal nanoparticles	Green H_2, obtained in the CO_2-reduction device	Yes	NH_3	TBD	Chemical industry, fertilizers
ICONIC / C	Seawater; agricultural wastewater runoffs	NO_3-	50-200 mg NO_3-/Seawater liter	TBD	No capturing materials	Electrochemical (C)	To be determined, but CRM-free catalysts	Additives for pH control	No	Urea	To be determined (mg/L)	Agriculture (fertilizer)
DAM4CO$_2$ / A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mi-Hy / D	Urine; urea	NH_3, NH_4^+	None needed/neat	No pretreatment needed	Biofilm bacteria on porous electrodes	Bio-electrochemical Systems (D)	No catalyst/ biological system	N/A	Yes	Electricity; potash; trona; struvite (magnesium ammonium phosphate)	TBD	Remote area utility; agriculture; possibly chemical industry
MINICOR / B	Nitrogen-rich biomass, wastewater	NH_3, NH_4^+	None needed/neat	No pretreatment needed	Porous biochar	Biochar adsorption (B)	N/A	N/A	Depends on feedstock and process setup	Replenished soil, purified water.	TBD	Agriculture

Annex B Portfolio activities

Portfolio actions include collaborations at least between two of the projects. The following list of portfolio actions will be revised and adapted, in accordance with the interests and needs of the projects. The aim of the project partners within the portfolio is to address the specific challenge objectives described in the call by carrying out, among others, the following actions.

Table 8. Portfolio activities

ACTIVITY	PROJECT IN CHARGE
Communication guidelines	CONFETI / ICONIC
List of participants including role, tasks and WPs involved	Mi-Hy
Maintenance of TEAMS documents / updates	CONFETI
Portfolio website	SUPERVAL
Vertical webinars	$DAM4CO_2$
Junior scientists meeting	HYDROCOW
List of equipment that can be shared with other projects	CONFETI
Project pitch deck	SUPERVAL / ICONIC
Project pitch video	All projects
Newsletter	ICONIC
Scientific conference / Mini-symposium at a large conference	$DAM4CO_2$
Website and Interactive digital platforms	SUPERVAL
Collaborative publications	The Programme Manager to nominate based on the topic
Hybrid seminar in connection to the annual meeting	ECOMO
Portfolio next meeting in 2024 (one day portfolio meeting + session on the portfolio within a conference the day after the portfolio meeting)	ECOMO
Video of the Kick-off Meeting	EIC
Identification of commonalities among projects (including final uses)	CONFETI / ECOMO / ICONIC
Techno-economic and environmental assessment	SUPERVAL
Policy, Regulatory and standardization/system analysis and integrations at EU level	HYDROCOW
Materials assessment	SUPERVAL
Markets assessment	$DAM4CO_2$
Sharing of laboratory instruments and adopting common characterization methodologies	$DAM4CO_2$
Identification of sub-portfolios	MINICOR
Other collaboration / funding opportunities	Mi-Hy
Stakeholder mapping & engagement strategy	To be developed during the innovation training course
Innovation training course	All projects
Meetings with Transition and Accelerator projects	All projects
Cooperation with other relevant HE funded projects	All projects
Potential cooperation with OITBs	All projects
Identification of the proper in-operando characterization	$DAM4CO_2$ / MINICOR
Exploitation strategy	To be developed during the innovation training course

Annex C Portfolio meetings

The Portfolio Kick-off Meeting took place in Brussels in hybrid model in November 2023 with the participation in person of all team leaders of the portfolio.

The first portfolio meeting was organized by HYDROCOW and took place in June 2024 in Helsinki. The location and dates of future meetings shall be decided no later than March 2025 and March 2026. Principal Investigator, the Portfolio Manager, the Innovation Manager and the Communication Manager) are expected to participate in these meetings. Participation of other projects members is also encouraged.

These meetings are also an opportunity to identify new specific collaborations between two or more projects leading to additional portfolio activities (e.g., sessions with SMEs and corporations, or with investors etc.) or needs for a revision of the portfolio activities. The PMs can also propose sessions to be added to the portfolio meeting and invite key stakeholders.

Table 9. Portfolio meetings

PORTFOLIO MEETING AND LEAD	DATE AND LOCATION TO BE DETERMINED BY	DATE OF THE PORTFOLIO MEETING	FINALIZED LOCATION OF THE PORTFOLIO MEETING
1st Portfolio Meeting HYDROCOW	Communication Managers	17-18th June	Helsinki
2nd Portfolio Meeting MINICOR	Communication Managers	Summer 2025	Naples
3rd Portfolio Meeting (TBD)	TBD	TBD	TBD

Annex D Non-disclosure obligations and Non-disclosure Agreements (NDAs)

According to the call:

"Where EIC awardees are informed on or given access or disclosure to any preliminary findings, results or other intellectual property generated by other EIC actions, and where this information is earmarked as confidential in accordance with section 2.1.b, they must:

- *keep it strictly confidential; and*
- *not disclose it to any person without the prior written consent of the owner, and then only under conditions of confidentiality equal to those provided under this section; and*
- *use the same degree of care to protect its confidentiality as the EIC awardee uses to protect its own confidential information of a similar nature; and*
- *act in good faith at all times; and*
- *not use any of it for any purpose other than assessing opportunities to propose other research or innovation activities to the EIC, or any other initiative agreed by the owner.*

The EIC awardee may disclose any such information to its employees and, with the prior authorisation of the owner, to its subcontractors established in a Member State or an Associated Country and:

- *who have a need to access it for the performance of their work with respect to the purpose permitted above; and*
- *who are bound by a written agreement or professional obligation to protect its confidentiality in the way described in this section.*

No obligations are imposed upon the EIC awardee where such information:

- *is already known to the EIC awardee before and is not subject to any other obligation of confidentiality; or*
- *is or becomes publicly known through no act by or default by/of the EIC awardee; or*
- *is obtained by the EIC awardee from a third party and in circumstances where the EIC awardee has no reason to believe that there has been a breach of an obligation of confidentiality.*

The restrictions in this section do not apply to the extent that any such information is required to be disclosed by any law or regulation, by any judicial or governmental order or request, or pursuant to disclosure requirements relating to the listing of the stock of the EIC awardee on any recognised stock exchange.

Upon the end or termination of the grant agreement or of the participation of the EIC awardee, it must immediately cease to use the said information, except if otherwise directly agreed with the owner, or if the EIC awardee remains a member of the EIC Community referred to under section 2.1.b.

The provisions of this section will be in force for a period of 60 months following the end or the termination of the grant agreement or of the participation of the EIC awardee, at the end of which period they will cease to have effect."

Facilitating exchange of information within the portfolio. Knowledge on the other projects is necessary for the definition of this implementation plan. As of October 2023, the only public information on the projects is title, abstract and information on project partners as well as received funding. If considered relevant, projects are encouraged to set-up and sign NDAs.

Facilitating exchange of information with "externals". If activities are organized with the participation of externals, the projects will assess whether an NDA with these external parties is needed and proceed accordingly.

CARBON DIOXIDE AND NITROGEN MANAGEMENT AND VALORISATION PORTFOLIO

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