PATHFINDER CHALLENGE
Carbon dioxide and Nitrogen management and valorisation

CHALLENGE GUIDE
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The EIC will hold an online Info Session on this Pathfinder Challenge call on 05/07/2022. Participation in the meeting, although encouraged, is optional and is not required for the submission of an application. Information about how to access the Info Session and on additional dissemination events can be found at EIC Pathfinder Challenges Applicants' Day (europa.eu) **and** EIC Pathfinder (europa.eu)**.**

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1. About this document

The Challenge Guide serves as guidance and background for the common understanding, participation rules and obligations for the EIC beneficiaries that are involved in the Challenge Portfolio. Contractual Obligations are further detailed in the EIC Work Programme https://eic.ec.europa.eu/eic-work-programme-2022_en and collected in the Pathfinder Challenge guidance on contractual issues, available on the Challenge page.

The Challenge Guide is a guidance document accompanying a Pathfinder Challenge call for proposals to provide applicants with additional technical information to underpin the objectives and to provide further information about how portfolio considerations will be taken into account in the evaluation of proposals.

The Challenge Guide is prepared by and under the responsibility of the relevant EIC Programme Manager (information about the EIC Programme Managers is available on the EIC Website https://eic.ec.europa.eu/eic-communities/eic-programme-managers_en). It further details the call by complementing notably the Scope, Specific Objectives and/or Specific Conditions set out in the EIC Work Programme. In no case does the Challenge Guide contradict or supplant the Work Programme text.

2. Background concerning the scope and objectives of the Challenge

This section provides additional information on the background in the relevant scientific and technological domains pertaining to scope and objectives of the Challenges that applicants may wish to take into account. This section should be read as background to the Challenge call in the EIC Work Programme text (attached as Annex). Proposals to this Challenge are expected to explain how they relate to and intend to go beyond the state of the art, and how they interpret and contribute to the objectives of the Challenge.

Policy background

The European Green Deal[1] sets ambitious targets for climate neutrality by 2050, in addition to biodiversity loss prevention, environmental emissions abatement and more sustainable deployment of natural resources and ecosystems. This requires breakthrough and integrated solutions to disrupt the current production processes, introduce more sustainable consumption habits and set up multidisciplinary approaches for the effective integration of processes and value chains[2].

[1] EU COM(2019) 640
[2] EU COM(2020) 953

Anthropogenic activities have strongly increased the carbon dioxide (CO_2) concentration into the atmosphere and highly distorted the global nitrogen (N) cycle in the last century[3]. This affects both climate change issues[4], eutrophication and the whole structure and function of ecosystems[5]. In this context, CO_2 and nitrogen (N) cycles belong to the approach of 'make, use and dispose' and their management includes capture, storage, conversion, use and recycle.

The implementation of sustainable CO_2 and N cycles is a key pillar to the net-zero emissions target[6]. In particular, the achievement of these targets requires a range of breakthrough technologies, potentially sustained by renewable energy, or advanced nature-based or nature-inspired solutions to increase CO_2 and N cycle efficiency via emissions abatement or net CO_2 and N removal approaches.

Carbon Capture and Utilization (CCU) and carbon capture and storage (CCS) are recognized as enabling technologies for climate neutrality[7][8][9]. These practices enable emissions reduction via concentrated CO_2 streams capture or removing CO_2[10] directly from atmosphere to balance emissions that cannot be avoided, and this is a critical part of "net" zero goals. By providing a sustainable and diversified source of raw materials, CCU also offers competitive advantage for European industries. Anticipating the net-zero goal from 2070 to 2050 requires a strong increase in CCU and CCS deployment, both capturing CO_2 from concentrated fluxes, such as emissions from fossil-based industries, and Direct Air Capture (DAC) and then utilizing it for different applications.

The European Commission also addressed the need to limit N losses and improve the management of N cycle[11] to reach clean air, the hydrosphere and surface water ''good status''[12], maintain biodiversity[13] and set up an environmentally friendly food supply chain[14]. In fact, anthropogenic N is a by-product of fossil fuel combustion. It enters remarkably the environment also via fertilizer/nutrients and is often applied in excess in agriculture[15], and poorly absorbed by plants; this causes further air, soil, and water N pollutions as well as climate impact.

Improvements in CO_2 and N cycle contribute to the goals of the Horizon Europe Missions. In particular, an optimization of CO_2 and N recovery/conversion/use could address the goals of: a) Mission Climate adaptation (i.e. development of drought resilient grasslands, optimized to

[3] W. Winiwarter, et al.,The INI European Regional Nitrogen Centre: Concepts and Vision, Just Enough Nitrogen, Springer, 2020
[4] IPCC report, Summary for policymakers, 2018
[5] Sutton et al 2013, Our nutrient world, Global overview on nutrient management
[6] IEA, Energy Technology Perspectives, Special report on CCUS, 2020
[7] EU COM(2020) 98
[8] EU COM(2020) 299
[9] EU COM(2020) 301
[10] I. Butnar, et al, Review of Carbon Capture Utilisation and Carbon Capture and Storage in future EU decarbonisation scenarios, CCUS SET-Plan, 2020
[11] EU COM(2021) 1000
[12] European Waters, Assessment of status and pressures, European Environmental Agency, 2018
[13] EU COM(2020) 380
[14] EU COM(2020) 381
[15] W. Steffen, et al., Science, 347(6223), 1259855, 2015

minimize denitrification and maximize carbon capture / photosynthetic efficiency) or b) Mission Ocean (i.e. hydrosphere and wastewater remediation via N and CO_2 recovery and/or biotransformation into added-value products), or c) Mission Soil (i.e. improving soil carbon stock via carbon farming, developing and sustainably using bio-fertilizers or phytoremediation techniques to capture and exploit CO_2 and N), or d) Mission Cities (i.e. enhancing air quality in cities via urban transport emissions management, developing building-integrated solutions such as CO_2 and NOx capturing via vertical farming or solar roofs, or proposing circular approaches for urban wastes recovery).

In this perspective, the European Environmental Agency is fostering research towards a "circular economy" with effective waste and CO_2 recycling strategies as a core task. The end-of-life commodities should be reused, recycled and resourced for a better life-cycle design[16]. It is therefore of paramount importance to stimulate innovation, develop breakthrough technologies for CO_2 and/or N management and valorisation at different scales (centralized at large industrial facilities premises or distributed and at small scale level), exploiting industrial symbiosis opportunities using when possible renewable energy and avoiding toxic and critical raw materials.

Technology background

This section presents some non-exhaustive examples of technologies and processes, for CO_2 and/or N management and valorisation in scope with the call.

CO_2 can be captured from concentrated streams through different technologies (i.e. absorption, cryogenic liquefaction/solidification, membrane separation, adsorption, calcium looping, chemical looping combustion, CO_2 microbial fixation). Among them, amine scrubbing (chemical absorption) represents the most implemented technology, with still many unsolved challenges (e.g., improved reaction kinetics). The research on CO_2 capture is focused on more efficient, cheaper, environmentally friendly solutions, able to treat high impurities in the CO_2 gas streams, such as membranes and high temperature looping[17]. The main research directions in post combustion CO_2 capture are new generation solvents for chemical absorption, advanced materials with improved permeability and selectivity for adsorption processes, membranes featuring high durability and impurities separation capabilities, new "oxygen carrier" or reactor design for chemical looping combustion as well as process improvements

[16] J. B. Zimmerman, et al., W. Leitner, Science, 80, 367-397, 2020
[17] Kapetaki Z., et al., Carbon Capture Utilisation and Storage Technology Development Report (CCUS) EUR 29909 EN, European Commission, Luxembourg, 2019, ISBN 978-92-76-12440-5, doi:10.2760/185420, JRC118297, 2018

for cryogenic and oxy-combustion technologies[18][19][20][21]. The development of these novel materials certainly could benefit from computational based design tools.

Atmospheric CO_2 removal via DAC technologies can be achieved via liquid or solid based processes. In the first case, the main solutions rely on new solvents and electrochemical regeneration methods for sorbents, while in the latter the research focuses on new CO_2 sorbents that could be integrated to disruptive DAC technologies. Several diverse and competing DAC approaches are emerging, adopting electrochemical devices, passive systems (e.g. physio sorbents), nature inspired solutions potentially integrated to engineered systems[22].

Rather than treating CO_2 as a waste, so disposing or sequestering it after its capture, the circular approach proposed in this Challenge aims at using CO_2 as a building block for the production of added value products (e.g., chemicals, building materials, C-source for fuels). In fact, CO_2 is a very versatile molecule that can be transformed into a large range of products, but it is also a stable molecule, so that its conversion process is in most cases energy intensive. Thus it is generally necessary to design efficient CO_2 conversion processes, potentially driven by renewable energy sources, and often relying on selective or hybrid catalysis (chemical and enzymatic), electrocatalytic or photocatalytic CO_2 reduction, or on engineered CO_2 conversion into new added-value products often based on biotechnology and nature-based or nature-inspired solutions.

The conversion of CO_2 into chemicals, either as final products or intermediates, can occur using different amounts of energy, depending upon the need to vary or maintain the C oxidation state and/or the use of H_2 (with potential integration to H2 economy). CO_2 is also used as feedstock in the production of urea for fertilisers, while its conversion into methanol at reasonable costs could pave the road to the production of a range of bulk chemicals such as ethylene or propylene or to the feeding of advanced fuel cells.

The main ongoing challenges in the (bio)chemical-electrochemical exploitation of CO_2 are associated to the combination of advanced biotechnological and catalytic processes, the development of nature-inspired energy efficient systems (i.e. bio-electrochemical approaches that merge electrochemistry and biotechnology), and the "broad" area of solar chemistry where photo-electrochemical approaches can originate different added-value products[23]. Other challenging approaches for CO_2 capture and sustainable and smart utilization are connected to the production of materials for the building and construction sector and renewable fuels of not biologic origin (RFNBO) whose market competitiveness is strongly link to cheap production

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[18] SAM HLG, Novel Carbon Capture and Utilisation Technologies, Luxembourg, 2018
[19] F. Nocito, A. Dibenedetto, Atmospheric CO2 mitigation technologies: carbon capture utilization and storage, Cur. Op. Green and Sust. Chem., 21, 34-43, 2020
[20] P. Madejski, et al., Methods and Techniques for CO2 Capture: Review of Potential Solutions and Applications in Modern Energy Technologies. Energies, 15, 887, 2022
[21] N.S. Sifat, A critical review of CO2 capture technologies and prospects for Clean Power generation, Energies, 12, 4143, 2019
[22] M. Erans, Direct air capture: process technology, techno-economic and socio-political challenges, Energy Environ. Sci., 15, 1360, 2022
[23] A. Dibenedetto, et al., The future of carbon dioxide chemistry, Chem. Sus. Chem., 13, 6219–6228, 2020

of renewable H_2. It is also a priority to intensify the yields of bioprocesses (i.e., through CO_2 fast, high yield and selective engineered enzymes or bacteria).

Carbon farming is a sustainable practice that rewards land managers for taking up improved land management as well as preserve EU food safety and security, resulting in the increase of CO_2 storage in living biomass and its lower release into the atmosphere. Furthermore, carbon farming practices often provide co-benefits on biodiversity and ecosystem services and help land managers being more resilient to climate change. Some examples of improved land management practices that result in the increase of carbon sequestration and in co-benefits for N cycle improvement, ecosystems and biodiversity and that are included in this challenge are: (i) sustainable forestry and agroforestry management (e.g. enhanced photosynthesis) based on biotechnologies for CO_2 capture; (ii) increase of soil organic carbon stock through biological capture of CO_2 and/or N (via biochar and compost applications, sustainable land cropping, restoration of peatlands and wetlands, etc..).

CO_2 utilization in building industry (e.g., carbonation technology) offers very high CO_2-mitigation potentials and is expected to be one of the first CCU that will achieve a widespread deployment. Anyway, many challenges, such as the use of different wastes for carbonated products or more efficient overall processes, are still to be overcome[24].

A promising nature-based options for CCU, which rely on the integration to water resources, is algae cultivation. Algae could be used to fix large volumes of CO_2 and produce high value chemicals, pharmaceuticals or nutraceuticals[25]and also fuels. The CO_2 capture with algae production can be integrated to wastewater treatment in ponds or bioreactors. The adopted processes and technologies are still under optimization in terms of reactors configuration, feedings and energy sustainability[26][27].

The global N cycle is central to the biogeochemistry of the Earth. The supply of N_r (reactive nitrogen including all inorganic reduced and oxidized N forms as well as organic N sources) is essential for all life forms. In the absence of human influences, Biological Nitrogen Fixation (BNF) and the production of NOx by lightning would be the only sources of new N_r in the environment. Increases in N_r supply due to anthropogenic activities have been exploited in the three following main areas: a) agriculture where N-based fertilizers are used to increase the yield of food crops, b) N-fixation in protein rich crops such as soy distributed to regions with intensive livestock breeding and converted into manure where it is used for crops and produces losses of ammonia to the atmosphere and nitrate to groundwater; c) energy production where NO_X comes from oxidation of atmospheric N_2 and/or of organic N in the fuel. Such an increase

[24] Q. Zhu, Development on CO_2-utilization technologies, Clean Energy, 3, 2, 85-100, 2019
[25] A. Dibenedetto in: An economy based on carbon dioxide and water, Eds.: M. Aresta, et al., Springer Publ., 2019, chap. 9
[26] C. Song, et al., Intensification of a novel absorption-microalgae hybrid CO_2 utilization process via fed-batch mode optimization. Int J Greenh. Gas Con., 82:1–7, 2019
[27] S. Liu S, et al., Growth and Nutrient Utilization of Green Algae in Batch and Semicontinuous Autotrophic Cultivation Under High CO 2Concentration, Appl. Biochem. Biotechnol. 2019, 188:836–853, 2019

of new N, estimated by over a factor of 10 in twentieth century compared to the late nineteenth century, has resulted in a very significant alteration of the N cycle in air, land, and water and at local, regional, and global scales inducing remarkable biodiversity losses and climate changes[28][29]. To address these issues, N needs to be managed in an integrated fashion, at a variety of scales (from global to local).

Due to the seven oxidation states of N, the numerous mechanisms of interspecies conversion, and of transport/storage in the environment, N cycle is the most complex among all most relevant elements and it can affect the environment at both global and local scale mainly depending upon human activities and weather conditions[30].
Short circuiting of the N cycle is technically possible, but it is too much energy demanding. From a cost perspective the large amount of required chemicals makes the present technologies not competitive yet. Breakthrough research is hence needed to enable sustainable N cycles with low energy input, or through integrated and circular approaches that use residual chemicals, wasted heat or biological waste (i.e., manure, wastewater, sewage sludge and waste food).

A major challenge of N cycle management and valorisation is to reduce losses of N from agriculture, industry, transport, and energy sectors. This can be achieved by reducing inputs in agriculture, increasing the N use efficiency and by replacing fossil fuels with renewable sources, which however excludes the recovery and use. On the other side, N reuse can be achieved via concentrating and recycling streams of N_r coming from different diluted sources or optimizing N_r capture-recovery techniques of NO_x from point source emissions mainly due to combustion processes, nitric acid from sewage-manure, nitric oxide from soil or combustion streams emissions, ammonium or nitrate ions from organic matter (e.g., crops, manure) or human wastes[31][32]. This goal may be achieved via membrane processes, filtration, vacuum distillation, N stripping, N chemical/biological oxidation and nature-based solutions such as bio-electrochemical systems, N fixation crops and/or phytoremediation (that could combine N and CO_2 capture with water cleaning) as well as circular/industrial symbiosis approaches integrating the use of residual chemicals and organic by-products[33][34]. Another major research challenge is represented by innovative sustainable N conversion processes (nitrogen fixation, nitrification, denitrification[35]), which can be achieved via N-transforming microorganisms, based on synthetic biology or via chemical processes (i.e., electrochemical, chemical looping, or low

[28] *J.N. Galloway, et al., Nitrogen cycles: past, present and future, Biogeochemistry 70: 153–226, 2004*
[29] *J.W. Erisman, et al., Consequences of human modification of the global nitrogen cycle. Phil. Trans. R. Soc. B 368, 20130116., 2013*
[30] *D. Fowle, et al., The global nitrogen cycle in the twenty-first century. Phil. Trans. R. Soc. B 368: 20130164, 2013*
[31] A.M. Leach, et al., A nitrogen footprint model to help consumers understand their role in nitrogen losses to the environment. Environ. Dev. 1, 40–66, 2012
[32] S. Reis, Synthesis and review: tackling the nitrogen management challenge: from global to local scales, Environ. Res. Lett. 11, 120205, 2016
[33] STOWA Report n.51, Explorative research on innovative nitrogen recovery, 2012
[34] A. Beckinghausen, From removal to recovery: an evalution of nitrogen recovery techniques from wastewater, Applied Energy, 263, 114616, 2020
[35] M. Kuypers, The microbial nitrogen-cycling network, Nature Reviews, Microbiology, 16, 264-276, 2018

temperature and pressure catalysis) to substitute the energy intensive Haber-Bosch and Ostwald processes. Alternative uses of N are other research topics, such as the production and use of ammonia (useful as energy carrier and energy storage material) and of nitric acid (for chemicals production), included their optimized use in agriculture to set up circular loop of nutrients[36].

An example of CO_2 and N cycle combined recovery (e.g., from combustion processes) is the formation of C-N bond in the industrial synthesis of urea, carbamates and isocyanates that are added-value products in the formulation of pharmaceuticals, agrochemicals, fuels additives and polymers[37]. The research challenges rely in this case on nature-based approaches, novel environmentally friendly catalysts, the integration of electrochemistry and biotechnology and less energy intensive chemical processes.

Background on the topic of the challenge

The call aims at funding non-incremental research to produce a proof of concept (or lab-scale validated) of an advanced process/technology/material able to capture, convert and use CO_2 and/or N in one or more specific sector(s)/application(s) and addressing both the needs to build a whole device as well as opportunities for system integration. The main target applications are CO_2 capture and use, not sequestration, from concentrated streams or air capture, and/or N recovery and recycle from air, soil, water or organic materials. The proposed technologies can address only CO_2, only N or both cycles in an integrated fashion. Proposals that focus only on capture and/or storage and do not include the final use are out of the scope of the call. Proposals could include CO_2 removal via its conversion into a) chemicals and materials, b) bio-based solutions able to return C (and N) into the soil (negative emission technologies) and/or c) renewable fuels (net zero technologies).

Proposals that aim at spatially decoupling the capture of CO_2/N and their final valorisation should specifically address the storage/transport issues and the potential integration with existing or new infrastructures by demonstrating the minimization of the whole process carbon footprint. Infrastructures for the safe transportation and temporary storing of CO_2 are considered essential for the rolling out of CCU technologies. The development of CCU-CCS hubs/centres of shared CO_2 transport and storage infrastructure is not the core scope of the call.

Secondary benefits of the proposed technologies, in particular if in line with the ambitions of the Missions "A Soil deal for Europe", "Restore our Ocean and Waters", "Climate-Neutral Cities" and "Adaptation to Climate change" (i.e., wastewater management, emissions reduction in industrial, urban or agricultural sector, bioremediation, buildings-integrated solutions for the removal of atmospheric pollutants or industrial symbiosis pathways) will be considered as an added value.

[36] The royal Society, Ammonia: zero carbon fertiliser, fuel and energy store, 2020
[37] M. Xu, Synthesis of urea derivatives from CO_2 and Silylamines, Angew. Chem. Int., 58, 5707–5711, 2019

Technologies that aim at reducing CO_2 and N emissions are included in the scope of the call if the recovery and valorisation of the emission are also addressed.

CO_2/N capture/valorisation technologies integrated with renewable heating/electric energy conversion (solar, geothermal, biomass) or waste heat recovery are in the scope of the call, especially if focused on the capture and use. CO_2 use in the fossil fuel-based economy, such as for enhancing oil recovery (EOR), is out of scope of the call.

Proposals should highlight the potential collaborations with key stakeholders during the project implementation and should mention their deployment strategy and the steps required to scale up the process. There should be a preliminary risk analysis to increase the probability of achieving each deliverable in the estimated time frame and with the allocated funding. Proposals should be flexible in modifying project targets and key directions, if needed, also recurring to the DBTL (design-build-test-learn) cycle.

Proposals are strongly encouraged to apply the life cycle thinking including the recovery and recycling of by-products. The safe use of not-environmentally harmful and not critical raw materials (CRM), or the recycle/reuse of CRM, is mandatory. Proposals should include a full life cycle analysis of the proposed solutions and their impact on Europe's decarbonisation goals.

Proposals should also address, 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.

3. Portfolio considerations for the evaluation of applications to the Challenge

This section describes how portfolio considerations will be taken into account in the second stage of the evaluation of applications. In the first stage, all applications will be evaluated individually by external experts and scored against the evaluation criteria set out in the Work Programme. All applications that pass the defined thresholds against the criteria will be included in the second stage of the evaluation. At the second stage, all above threshold applications will be considered collectively by an evaluation panel chaired by a relevant Programme Manager. At this stage, the Evaluation Committee will consider which applications to recommend for funding in terms of a coherent portfolio of projects that can interact, reinforce or compete with each other to increase the overall impact.

The EIC Carbon dioxide and nitrogen management and valorisation portfolio activities will encourage synergies with other funded projects, national and European innovation ecosystems and actions funded by the European Commission in the same field.

Categories

The portfolio building process will be based on a balance of complementarities and diversities among the proposals. The evaluation committee will firstly identify a sufficiently broad range of diverse and competing approaches and technologies classified in categories. Secondly, it will look for shared components among proposals within such categories. For this purpose, the proposals will be classified in the frame of the following categories:

I. Molecule removal: the proposal can address the removal and valorisation of CO_2, N or both.
II. Type of stream from which CO_2 and N are recovered e.g. concentrated streams (point source), air, water, soil, etc.
III. Scale levels of the applications such as large-scale centralized solutions (i.e. fossil or biomass power plants, industrial sector symbiosis) and small scale / distributed fashion solutions (i.e. transport or residential sector).
IV. Removal/valorisation of CO_2 and N processes e.g. biological or nature-based/inspired processes (using plants, microbes, etc), chemical, electrochemical processes (photoelectrochemical, bio-electrochemical, etc), and thermo-physical processes (plasma based, thermally driven etc).
V. Final use e.g. conversion and use of CO_2 and/or N for materials and or chemicals and fuels, for industrial, agricultural, building applications.
VI. Secondary added benefits e.g. clean water and intensified food crop production, circularity in food production, emissions reductions, bio/phytoremediation of impacted matrices, improvement of biodiversity and climate adaptation, etc..
VII. Systems integration e.g., coupling the processes to renewable energy, green hydrogen pathways, waste energy recovery, retrofit of power plants for sector coupling options (to produce fertilizers, bulk chemicals, or other commodities), buildings or greenhouses integrated solutions.
VIII. Methodologies for materials and components selection/optimization e.g., adoption of different approaches such as computational chemistry to select the material at components/devices/system level.

Portfolio considerations

The Evaluation Committee will aim at composing a portfolio of projects taking into account the following considerations:

- Compose a portfolio of proposals for removal of CO_2, N, or both molecules with a diversity of recovery and valorisation technologies, sources of recovery, and scale/size levels.
- The portfolio will be built from proposals diversifying the final use, secondary added values and approaches for materials/components selection/optimization.
- While building the portfolio we will aim at including complementary proposals, covering all the aspects of systems integration.

4 Implementation of the Challenge portfolio

Once selected, projects will be expected and obliged to work collectively during the implementation of their projects under the guidance of an EIC Programme Manager. This section summarises some of the key aspects of this pro-active management which applicants should take into account in preparing their proposals.

Grant negotiations

Applicants may be requested to make amendments to their proposed project in order to take into account the portfolio objectives and enhance the portfolio. Such changes may include: an additional work package to undertake common/ joint activities (workshops, data exchanges, joint research, etc) with other projects in the portfolio; adjustments to the timings of some activities and deliverables in order to synchronise better with the implementation timings of other projects; adjustments to the timings of some activities and deliverables in order to synchronise better with the implementation timings of other projects; specific target changes to improve complementarity/ comparability with activities and results from other projects. All such changes will be discussed during the grant preparation stage with the aim of reaching a consensus between all projects on the adjustments needed.

Challenge portfolio roadmap

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 in light of 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.

Tools for proactive management of projects

Projects in the portfolio may be offered additional support, either individually or collectively, in order to reinforce portfolio activities or explore the transition to innovation. Such additional support includes:

- Booster grants of up to €50k (see Annex 6 of the EIC Work Programme)
- Access to additional EIC Business Acceleration Services (see https://eic.ec.europa.eu/eic-funding-opportunities/business-acceleration-services_en)
- Access to the Fast Track to the EIC Accelerator, the decision for which would follow a project review (see Annex 4 of the EIC Work Programme)
- Access to the EIC Market Place, once operational, to connect with innovators, investors and other selected partners

- Interactions with relevant projects and initiatives outside the portfolio, including other EU funding initiatives as well as those supported by national, regional, or other international bodies.

ANNEX Extract of EIC work programme

II.2.1 EIC Pathfinder Challenge: Carbon dioxide and nitrogen management and valorisation

Introduction and scope

Climate change, global warming and water/soil pollution are unprecedented challenges for the planet. To overcome them, it is necessary to develop breakthrough and integrated solutions to disrupt the current production processes and introduce more sustainable consumption habits. Carbon dioxide (CO2) and nitrogen (N) flows strongly affect climate change and belong to the cycle of make, use and dispose. To implement CO2/N sustainable cycles there is the need to develop technologies, sustained by renewable energy, able to increase their cycle efficiency introducing novel management and valorisation practices and approaches.

This EIC Pathfinder Challenge aims at developing novel processes and technologies to enable CO2 and N management/valorisation and in turn to reduce:

- greenhouse gas (GHG) emissions,
- nitrogen losses (mainly due to agricultural practices), so minimizing impact on soil and water,
- carbon losses from the energy, industrial, agricultural, and livestock sectors.

These technologies could also increase cross sector coupling of energy systems, when renewable energy is required to capture, convert and use carbon and nitrogen streams into added value products.

This Challenge focuses on new biological, chemical, physical routes that integrate the capture and/or recovery of CO2 and N species, storage and their conversion into value-added products, and/or net zero commodities, chemicals, fuels and energy vectors. The processes should focus on the use of renewable energy 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 research could address in an integrated manner environmental, industrial, agricultural, socio-economic and logistic issues.

Specific objectives

The proposals, through non-critical raw materials (CRM)-based, systems integrated, life cycle and circular thinking driven approaches, should develop a proof of concept (PoC) or lab-scale validated innovative technology that, will manage and valorise CO2, N, or both at the same time into value-added net zero commodities, chemicals, fuels, or energy vectors. Such technology should produce added-value products optimising input/output energy balances and achieving a carbon negative or net zero process promoting sustainable business models. Besides, the different steps of the CO2/N management and valorisation process could be designed to achieve integration at system or process level, to maximize sector coupling of energy systems such as converting renewable electricity into e-fuels and materials (e.g., power to X).

Expected outcomes and impacts

This Challenge aims at developing:

- a net zero carbon process involving conversion of CO_2 from various sources and streams into renewable fuels or net zero materials, using renewable energy as input. Such technology should involve CO_2 capture/conversion (directly from air or from flue gases streams, and through photosynthetic, biological, biophysical, or chemical processes), storage (e.g. through chemical, electrochemical, biogenic processes), and further valorisation (e.g. feedstock for chemical industry, high energy density fuels, energy carriers or other carbon neutral compounds for industrial or agricultural applications). The CO_2 valorisation processes should be based on renewable energy and adopt technologies such as co-electrolysis of CO_2 and water, catalytic reduction of CO_2, or photoelectrochemical CO_2 conversion etc.
- N integrated management cycle (nitrogen circular economy) to avoid or significantly reduce N release (e.g. from combustion, fertilizer, livestock, and wastewater) in conjunction with the conversion of N-compounds to inert N_2, or N-compounds recovery (e.g. using chemical, electrochemical, physical or biological systems), recycle and reuse as feedstock for added-value products or for biological fixation (e.g. into agriculture, as ammonia, as renewable fuels and energy vectors, as liquid hydrogen carriers).

Specific conditions

Applicants should propose a proof of concept or lab-scale validated innovative technology able to manage and valorise CO_2 and/or N by biological, chemical, or physical routes without the use of critical raw materials, using renewable energy as sources and not being harmful to the natural ecosystems.

Projects with multidisciplinary and cross-sectorial approaches, looking for inspiration, ideas and knowledge in a broad range of disciplines are particularly welcome. The safe and sustainable use of non-critical raw materials is mandatory, and the projects should include a full life cycle analysis of the proposed solutions and their impact on Europe's decarbonisation goals.