European Innovation Council

CHALLENGE GUIDE

PATHFINDER CHALLENGE: Towards cement and concrete as a carbon sink

EIC Work Programme reference: HORIZON-EIC-2024-PATHFINDERCHALLENGES-02
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The EIC will hold an Info Session on this Pathfinder Challenge call on March 20, 2024, between 09:00 and 13:00 CET. Participants can access the meeting as guests at https://webcast.ec.europa.eu/information-day-eic-work-programme-2024-pathfinder-challenges-2024-03-20.
Participation in the meeting, although encouraged, is optional and is not required for the submission of an application. A recording of this Info Session will be made available on the same URL. Notifications of additional dissemination events can be found at https://eic.ec.europa.eu/events/save-date-european-innovation-council-pathfinder-challenges-work-programme-2024-info-day-2024-03-20_en.

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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 2024 https://eic.ec.europa.eu/system/files/2023-12/EIC-workprogramme-2024.pdf

The Challenge Guide is a guidance document accompanying a Pathfinder Challenge call for proposals 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 complements the Scope, Specific Objectives and/or Specific Conditions set out in the EIC Work Programme by a description of the portfolio considerations and how a portfolio will be built. The presentation provided by the Programme Manager during the Info Day will give applicants a further opportunity to understand the background of the call, and to ask questions to the Programme Manager. In no case does the Challenge Guide contradict or supplant the Work Programme text.

Following the selection of a proposal to be funded under the Challenge, the Programme Manager will work together with the consortia of the selected projects to develop a common roadmap with a strategic plan for the Challenge. This roadmap/ strategy plan will integrate the activities and milestones of the individual projects into a shared set of objectives and activities across and beyond the projects. The roadmap serves as a common basis for the project portfolio and may affect the project implementation - including possible adjustments, reorientations, or additional support to projects. The roadmap will be updated in light of emerging results or issues during the implementation.

2. The scope and objectives of the Challenge as defined in the Work Programme

This section is a copy of the Challenge call in the EIC Work Programme text. 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.

2.1 Background and scope:

Cement is the largest manufactured product in the world by mass. In 2022 humans produced 4,2 billion tons of it (about 626 kg per capita). Combined with water, sand and aggregates

cement is the glue to form concrete. Aside from water, there is no material we use more than concrete. Contractors can combine concrete with steel reinforcement bars to mould and create the build environment in which we experience our lives. The industry is interrelated with other major sectors such as energy and steel. Its supply chains are vast, deeply complex, with increasing degrees of fragmentation going downstream. This complexity is also reflected in the many ways cement and concrete markets can be (sub-) segmented, for example by cement use (concrete, mortar, etc.), concrete use (reinforced, non-reinforced, ready-mix, precast products, etc.), end-use (residential, non-residential, infrastructural, energy, etc.) to name a few.

Cement and concrete are versatile, low-cost, abundant and relatively local. Modern societies are hard to imagine without these materials. Realistically, cement and concrete are here to stay. Then again, current mainstream cement and concrete technologies are also the source of 8% of our CO2 emissions (about 600 kg per capita), which are "embodied" in our buildings and infrastructures. Roughly 60% of these emissions are "chemical" released by converting limestone into clinker, and 40% of doing so at very high temperatures by burning fossil fuels. With EU (and global) commitments for rapid and radical emission reductions, it is necessary to pull all scientific, economic, and regulatory levers to reduce the environmental impacts of the cement and concrete sector.

One default pathway to decarbonize cement (and indeed a major element in the sector's strategy to decarbonize to net-zero by 2050) is to capture and store CO2 of current production processes, Carbon Capture Storage (CCS). Technologies for CCS are in development and expected to increase the cost of cement. To avoid additional costs of future emissions as much as possible, accelerated deep-tech innovations are needed to fully negate or even absorb emissions by the sector in future. The breakthrough innovations sought with this Pathfinder Challenge aim to be more cost effective than CCS. Moreover, this Pathfinder Challenge encourages breakthrough innovations that utilize CO2. Such innovations can play an important role in future Carbon Capture Utilisation Storage (CCUS) economies, and trigger future revenue opportunities for the sector by offering negative emissions at scale. However, CCS/CCUS technologies that are unrelated to cement, and concrete technologies are out of scope of this Pathfinder Challenge.

This Pathfinder Challenge seeks to support breakthrough innovations and (alternative) pathways for decarbonized and carbon-negative cement and concrete. Future pathways must meet some important conditions to be ultimately successful.

- The economical and abundant availability of feedstock at the place of production (cement) and consumption (concrete) is an important condition for implementing practically viable alternative cement chemistries, concrete mixtures and substitute materials.
- Most of the consumption growth of cement (and associated CO2 emissions) is expected in developing nations. Therefore, if innovative (deep tech) solutions for cementitious materials are to be adopted on a significant scale (a condition for

"disruptive innovation") they shall (at least in potential) be low cost and used easily by people with minimal training and scientific knowledge.

- Ultimate success and technology adoption shall depend on meeting or exceeding the mechanical and operational performance levels of the incumbent mainstream cement and concrete technologies, which are also reflected in the various norms and standards.

2.2 Specific objectives:

This challenge is supporting the development of breakthrough technologies in one or more of the following domains:

(1) Advanced technologies that change the paradigm of prevailing binder technologies with alternative low-carbon compounds based on alternative feedstocks (e/g magnesia-based, (ultra-) mafic rocks), and curing processes (e/g carbonation curing), and the combination thereof. Widespread adoption of such radical new pathways will also need breakthrough innovations in energy efficient industrial production processes. Such engineered carbon mineralisation pathways (e/g MOMS) can in principle utilize and store large amounts of CO2 with high permanence and (CCUS) value in the final mortar and (reinforced) concrete applications. As the alternative feedstocks often formed the host rocks for valuable ores, some mine waste could contain accessible, abundant, and useful raw materials.

(2) Advanced technologies for a more efficient use of clinker in cement (reducing its clinker fraction), and of cement in concrete compositions (binder efficiency).

- For cement, radical innovations are sought that further extend the use of supplementary cementitious materials (SCMs), and that give access to novel, abundantly available alternative sources of reactive SCMs compared to the prevailing SCM materials that have limited (or even declining) availability.
- For concrete, the amount of binder used to produce concretes of a given strength can vary considerably (e/g depending on use case and geographical location). This points to substantial CO2 mitigation potential with innovations that solve for a consistently more efficient use of cement, for example. Through innovations that optimize and control particle size distribution (e/g more sophisticated grinding processes) in combination with compatible admixtures, and technologies that support industrialization to reduce variability of binder intensity and reduce waste.
- Novel reinforcement technologies may further improve efficient use of cement in reinforced concrete (e/g consumption driven by concerns about steel corrosion) and may be necessary for novel pathways for cement and concrete technologies that are not compatible with steel reinforcement.
- Novel pathways for compatible and equally performing "synthetic aggregates" may offer additional potential for CCUS at the concrete-mix level.

(3) Advanced technologies that lower or negate the need for burning fossil fuels to avoid the associated CO2 emissions. For example, novel breakthrough process innovations to manufacture decarbonized lime (e/g at low process temperatures, by non-thermal processes, electrified processes).

(4) Enabling technologies in support of (1), (2) and (3) based on technologies for computational material science or data-driven science (including AI and ML). There is a need for breakthrough simulation and prediction technologies that enhance the understanding of the characteristics and interactions of raw materials, hydration processes and microstructural development of cementitious materials. If generalizable technologies can be adapted to a wide variety and variation of real-world raw materials without the need for extensive local empirical testing, this would greatly enhance and accelerate development cycles, knowledge acquisition, discovery, and implementation.

2.3 Expected outcomes and impacts:

Project results must clearly demonstrate validation in laboratory environment (TRL4) of the breakthrough technology.

The portfolio of projects selected under this Pathfinder Challenge is expected to cover the four domains mentioned in the previous section. The collaboration between the selected projects is expected to be mutually beneficial and contribute to a further reduction of carbon emissions of cement and concrete. For example, the projects selected under 1, 2 and 3 will be required to closely collaborate with the project selected under 4, so that this project can provide additional guidance to the projects on plausible pathways.

In addition, projects are required to develop common metrics and terminology to compare project results. The results of each project shall include a rough order of magnitude (ROM) estimation of the potential impact the breakthrough technology can have on emission reductions. A portfolio activity that results in quantitatively stating the decarbonization potential of all portfolio projects combined is encouraged.

Also, portfolio activities to develop techno-economic views on the future implementation, adoption, and scaling potential of the various technologies in realistic real-world conditions, coupled with a view on an entrepreneurial path towards future commercialisation are strongly encouraged. Realistic expectations of operational conditions in those markets where future growth is expected most is critical for the adoption of innovative technologies at scale. For example, feed stocks required for some novel pathways may be found at different locations than existing quarries and cement plants. This requires a strategic rethinking of the cement and concrete value chains and distribution channels in target markets. Also, novel pathways utilizing CO2 for curing will require a stream of (likely) purified CO2, which triggers additional supply chain considerations. Other novel pathways may adopt to existing cement and concrete value chains and distribution channels as an innovation strategy for fast scaling and wide market adoption.

Any innovation that offers a reduction of CO2 emissions shall still enable, meet, or exceed the performance and workability criteria of the incumbent products it enhances or substitutes by the time of market adoption, as referenced by various industry norms and standards. It is expected that the collaboration between the portfolio projects will positively contribute to the understanding of this topic.

In the long run, it is expected that project results will form the basis for the development of novel cement and concrete products, production processes, and other solutions that impact the sector in its efforts to decarbonize and even absorb CO2 in step with the ambitions of the European Green Deal.

The portfolio of supported projects shall also contribute to medium to long-term impacts such as increasing EU technological leadership and reducing EU dependency on critical raw materials supply.

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. For more details of the full evaluation process please refer to the EIC Work Programme.

3.1 Categories and components/values

The four objective domains (alternative binder technologies, clinker fraction and binder efficiency, energy and emissions reduction, enabling technologies) are often mutually interdependent and will be the main categories we will use to build a portfolio of projects. The projects in a portfolio, addressing one or more of these domains, are expected to mutually benefit from each other, complement each other, share certain components with each other, as well have challenges in common. For example, a project on a breakthrough enabling technology may both be beneficial to and be validated by other portfolio projects. Also, joint understanding of policies, standards, industry supply chains, and sector stakeholders will benefit all projects towards the future commercialization of their technologies.

The four major categories and their components/values are depicted in the table below. The lists of components aims to provide exemplary guidance and considerations for the evaluation committee and are non-exhaustive.

Categories	**Components/values**
Alternative binders and processes	• Alternative binder technologies (e/g MOMS) • Alternative feedstocks (e/g magnesium rocks, industrial waste, mining waste)

	• Carbonation curing technologies • Others
Clinker fraction and binder efficiency	• Alternative SCM technologies • Synthetic aggregates (e/g carbon sink aggregates) • Particle size distribution control • Advanced admixtures • Mixture variability control • Novel reinforcement technologies • Others
Energy and emission reduction	• Alternative processes (e/g electrochemical) • Electrification of high temperature processes • Technologies reducing process temperatures • Others
Enabling technologies	• Advances in computational material science • Advances in AI/ML data technologies • Advances in imaging, scanning technologies • Others

3.2 Portfolio considerations

For building the portfolio of projects to be funded, the evaluation committee will apply the following portfolio considerations:

The objective domains of all proposals will be mapped against the four categories (alternative binder technologies, clinker fraction and binder efficiency, energy and emissions reduction, enabling technologies). It is possible that a proposal covers one, two, three or all four categories. The portfolio of projects selected under this Pathfinder Challenge is expected to cover the four objective domains.

The objective domains of all proposals will also be mapped against sub-categories as depicted in the table. The evaluation committee will also aim to compose a portfolio covering a diversity of sub-categories.

Within and among these categories, the evaluation committee will look at shared components or potential complementarities among the projects to identify a clear added value for the development of synergies and collaborations among the projects in the portfolio. For example, shared components or potential complementarities could for example relate to

overlap of, and/or the mutual interdependency between alternative binder technologies and processes that reduce energy consumption, or synthetic aggregates based on industrial waste enabled by advances in particle size distribution and AI/ML data technologies, etc.

In the overall composition of the portfolio, a preference shall be given in the number of projects allocated to the first objective domain (alternative binder technologies), while for the objective domain on enabling technologies, it is considered that in most cases one project will be sufficient. Just for illustration purposes: following this preference the number of projects allocated to the four objective domains could (within overall budget constraints) for example be: 3, 2, 2, 1 (or other reasonable distributions). The objective of this preference is to balance the portfolio towards a breakthrough potential of cement and concrete as a carbon sink.

Starting from the highest ranked proposal, a portfolio of proposals will be selected based on shared components/complementarities, while ensuring diversity among the selected proposals and coverage and preferred balance over the four categories. This implies that if the evaluation committee considers that a highly ranked proposal does not have a shared component/complementarity with other proposals, it will not be selected for the portfolio. To ensure diversification, proposals which the evaluation committee considers to be very similar to a proposal already included in the portfolio will not be selected.

Consequently, this means that the projects selected for funding after the second step may differ from the ranking list established from the first step (i.e., the score-based ranking after assessment of each proposal separately).

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.

4.1 Proposal preparation and grant negotiations

Applicants may be requested to make amendments to their proposed project to take into enhance the portfolio. Such changes may for instance include additional tasks to undertake common/ joint activities (workshops, data exchanges, joint research, etc) with other projects in the portfolio.

Based on first experience, it is advised to foresee in your proposal a dedicated work package for portfolio activities and to allocate at least 10 person-months (see below for the purpose and examples of such activities). You may propose concrete activities or remain generic in your description.

If you fail to do this during proposal time, your proposal will not be scored lower during the evaluation, but in case your proposal is selected for grant agreement preparation, you will be requested to add the portfolio work package to your grant agreement. Please be aware that in that case the maximum grant you receive will not change, and you will need to find the resources for portfolio activities within the foreseen project budget.

4.2 Challenge portfolio roadmap/ strategy plan

The portfolio aims at:

1) Reduction of carbon emissions of the cement and concrete supply chains
2) Enhancing the opportunities of the four objective domains (alternative binder technologies, clinker fraction and binder efficiency, energy and emissions reduction, enabling technologies), because of its active participation in the portfolio activities: ensuring that portfolio members, can build key partnerships for their future value chains.
3) Enhancing the commercialisation potential of the individual projects in the portfolio, because of its active participation in the portfolio activities: Ensuring that portfolio members, can access the right industry partners to explore key partnerships.

In order to accomplish the above the Programme Manager needs to develop and agree on a strategy plan for the portfolio with the portfolio projects.

4.3 Portfolio Strategy Plan

Following the selection of a proposals to be funded under the Challenge, the Programme Manager will work together with consortia of the selected projects to develop a common strategy plan/roadmap for the Challenge. This plan will integrate the activities and milestones of the individual projects into a shared set of specific objectives and activities across and beyond the projects. The roadmap serves as a common basis for the project portfolio and may affect the project implementation - including possible adjustments, reorientations, or additional support to projects. The roadmap will be updated in light of emerging results or issues 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/ strategy plan will include activities on technology, regulation, transition of technology to innovation, communication and dissemination of the portfolio. It will stimulate business opportunities. These activities may be reinforced during the implementation with additional funding and expertise through pro-active management.

Non-exhaustive examples of activities towards the above-mentioned aims are:

Technology

- The collaboration and interaction of the selected portfolio of projects is expected to further enhance their contribution to a reduction of carbon emissions of the cement and concrete supply chains. Therefore, integrative portfolio activities are encouraged that result in collective insights amongst the projects, or quantitatively stating the optimized decarbonization potential of all portfolio projects combined.
- Providing access to Open Innovation Test Beds and other research infrastructure.

Regulation

- Innovations that offer benefits of CO2 emission reductions shall still enable, meet, or exceed the performance and workability criteria of the incumbent products they enhance or substitute by the time of market adoption, as referenced by various norms and standards. It is expected that the collective networks and interactions of the portfolio projects will positively contribute to this understanding. Portfolio activities that support, inform, participate in discussions around, or identify gaps in on-going legislative processes (e/g development of standards) both for the construction sector as well as for EU carbon markets (e/g CCUS) are encouraged.

Transition of technology to innovation

- Portfolio activities developing techno-economic views on the future implementation, adoption, and scaling potential of the various technologies in realistic real-world conditions, coupled with a view on an entrepreneurial path towards future commercialisation are strongly encouraged. Realistic expectations of operational conditions in those markets where future growth is expected most is critical for the adoption of innovative deep-tech cement and concrete technologies at a significant scale and impact.
- Market analysis: Map the targeted players in a market and exchange the market research analysis results with other the portfolio projects to identify specific players with which the entire portfolio can establish partnership(s) of much higher impact as opposed to that of the individual project.
- Discussions on IP, licensing and business models and commercialisation strategy.

- Providing access to new markets through multipliers like Enterprise Europe Network.

Communication and dissemination

- Effectively communicate of any key outcome of the research work of the portfolio members collectively and/or an individual project, to early stage private and corporate investors focused on the same field. Such communication might also be addressed to the general public to increase social acceptance for proposed solutions, or to other researchers and stakeholders through common dissemination activities at scientific conferences or trade fairs.

These tasks require the active participation of portfolio members to a series of meetings called for and steered by the Programme Manager. Portfolio projects will be expected to exchange information on the proposed research methodologies, experimental tests, techno-economic input data and relevant results achieved, to collectively use the available resources. This exchange of data between portfolio members can enhance the potential of individual projects, use of results originating from the analysis of common databases, as well as their chances to establish key partnerships. The exchange of information for the purpose of EIC portfolio activities will fall under the conditions and non-disclosure obligations as specified in the EIC Work Programme 2024 (Annex 6, section 2).

4.4 Tools though which projects can receive additional support

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 5 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, which would follow a project review (see Annex 3 of the EIC Work Programme).
- The possibility to apply for EIC Transition if your Pathfinder project resulted in an experimental proof of concept (TRL 3), or a technology validated in the lab (TRL 4).
- 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.