Horizon Europe

Work Programme 2023-2024

Climate, Energy and Mobility

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Please note that:

- This document is work in progress and subject to changes.
- Budgetary information included in this document is preliminary.
- Implementation aspects (calls, lump sums etc.) are not yet included.
- Actions may be added, removed, merged or changed in future versions.

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Introduction

The overarching driver for this cluster is to accelerate the twin green and digital transitions and associated transformation of our economy, industry and society with a view to achieving climate neutrality in Europe by 2050. This encompasses the transition to greenhouse gas neutrality of the energy and mobility sectors by 2050 at the latest (as well as that of other sectors not covered by this cluster), while boosting their competitiveness, resilience, and utility for citizens and society. Europe has been at the forefront of climate science and is committed to keep delivering the knowledge for enabling efficient pathways and just transitions to climate neutrality.

Activities of this work programme support the implementation of the Paris Agreement and the United Nations Sustainable Development Goals [1]. By creating more jobs, accelerating economic and social transformation, faster digitalisation and by generating innovation-based and inclusive growth, activities will aid Europe's recovery[2] in the wake of the Covid-19 crisis, contributing directly to the Commission priorities of a European Green Deal, a Europe fit for the digital age, and an economy that works for the people.

The European Climate Law[3] requires the EU economy and society to become climate-neutral by 2050 in a socially fair and cost-efficient manner and, as an intermediate target, to reduce net greenhouse gas emissions by at least 55% by 2030 (compared to 1990 levels). To deliver on these targets, the Commission proposed 'Fit for 55' legislative packages in July[4] and December[5] 2021.

Research and innovation plays a central role in accelerating and navigating the necessary transitions; deploying, demonstrating and de-risking solutions; and engaging citizens in social innovation. The rate at which European research and innovation actions succeed in developing, upscaling, implementing, and commercialising innovative solutions will steer EU's future competitiveness of its existing and newly emerging industries in European and global markets.

[1] Activities in this cluster will contribute to multiple SDGs, with the most direct impact on SDG 7 (Affordable and clean energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action). In addition, SDG 3 (Good health and well-being), SDG 6 (Clean Water and Sanitation), SDG 8 (Decent work and economic growth), and SDG 12 (Responsible production and consumption) will be positively impacted.

[2] Europe's moment: Repair and Prepare for the Next Generation, EC COM (2020) 456 final

[3] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')

[4] Including actions on renewable energy, energy efficiency, CO2 emission standards for cars and vans, alternative fuels, energy taxation, and creation of a new Social Climate Fund.

[5] Including actions on Trans-European Networks, Intelligent Transport Systems, a European Urban Mobility Framework, reducing methane emissions in the energy sector, decarbonisation of the EU gas market, energy performance of buildings, and sustainable carbon cycles.

Cluster 5 supports the EU's strategic objectives through activities included in this work programme and through the support of Institutional European Partnerships [6] which are implemented through dedicated structures. Although the latter activities are not included in this work programme, it is of great importance to maximise synergy and coherence between activities regardless of their implementation mode[7].

Activities in this work programme will contribute to all **Key Strategic Orientations (KSOs)** of the Strategic Plan (KSO C being the one with the most direct contribution):

A. **Promoting an open strategic autonomy[8] by leading the development of key digital and, enabling and emerging technologies, sectors and value chains** to accelerate and steer the digital and green transitions through human-centred technologies and innovations;

B. **Restoring Europe's ecosystems and biodiversity, and managing sustainably natural resources** to ensure food security and a clean and healthy environment;

C. **Making Europe the first digitally enabled circular, climate-neutral and sustainable economy** through the transformation of its mobility, energy, construction and production systems;

D. **Creating a more resilient, inclusive and democratic European society**, prepared and responsive to threats and disasters, addressing inequalities and providing high-quality health care, and empowering all citizens to act in the green and digital transitions.

To contribute to these programme-level KSOs, cluster 5 will deliver on six specific **expected impacts**. In this work programme, each expected impact has been transformed into a specific **Destination** (see table below). This Destination-based work programme structure follows a thematic centre-of-gravity approach, but activities in a given Destination can of course have a cross-cutting character and will often contribute to multiple expected impacts. The specific contribution to the overall expected impacts is explained in the introductory text of each Destination.

Expected Impact (Strategic Plan)	**Destination (Cluster 5 work programme)**
Transition to a climate-neutral and resilient society and	1. Climate sciences and

6 Clean Hydrogen, Transforming Europe's rail system, Integrated Air Traffic Management, Clean Aviation

7 Activities specifically targeting fuel cells and hydrogen are primarily supported through calls for proposals of the European Partnership on Clean Hydrogen. However, in justified cases and in line with topic descriptions, specific aspects of hydrogen and fuel cells can be supported outside of the Clean Hydrogen Partnership

8 'Open strategic autonomy' refers to the term 'strategic autonomy while preserving an open economy', as reflected in the conclusions of the European Council 1 – 2 October 2020.

economy enabled through advanced climate science, pathways and responses to climate change (mitigation and adaptation) and behavioural transformations.	responses for the transformation towards climate neutrality
Clean and sustainable transition of the energy and transport sectors towards climate neutrality facilitated by innovative crosscutting solutions.	2. Cross-sectoral solutions for the climate transition
More efficient, clean, sustainable, secure and competitive energy supply through new solutions for smart grids and energy systems based on more performant renewable energy solutions.	3. Sustainable, secure and competitive energy supply
Efficient and sustainable use of energy, accessible for all is ensured through a clean energy system and a just transition.	4. Efficient, sustainable and inclusive energy use
Towards climate-neutral and environmental friendly mobility through clean solutions across all transport modes while increasing global competitiveness of the EU transport sector.	5. Clean and competitive solutions for all transport modes
Safe, seamless, smart, inclusive, resilient, climate neutral and sustainable mobility systems for people and goods thanks to user-centric technologies and services including digital technologies and advanced satellite navigation services.	6. Safe Resilient Transport and Smart Mobility services for passengers and goods

According to the **intervention logic** of this work programme, Destination 1 fosters climate science and thus helps to identify effective and efficient pathways and responses to climate change. Destination 2 supports different cross-cutting technologies and solutions for climate, energy and mobility applications. Destination 3 and 4 focusses mainly on energy issues – Destination 3 on making energy supply more sustainable, secure and competitive; Destination 4 on reducing energy demand of buildings and industry and enabling their more active role in a smart energy system. Destination 5 and 6 improve the performance of transport modes and mobility solutions – Destination 5 increases the competitiveness and climate/environmental performance of different transport modes; Destination 6 advances mobility services and solutions at system level for passengers and goods.

Horizon Europe is the EU's research and innovation support programme in a system of European and national funding programmes that shares policy objectives. Through the programme, special attention will be given to ensuring cooperation between universities, scientific communities and industry, including small and medium enterprises, and citizens and their representatives, in order to bridge gaps between territories, generations and regional cultures, especially caring for the needs of the young in shaping Europe's future. Calls could be EU Synergies calls, meaning that projects that have been awarded a grant under the call could have the possibility to also receive funding under other EU programmes, including relevant shared management funds. In this context, project proposers should consider and actively seek **synergies** with, and where appropriate possibilities for further funding from, other R&I-relevant EU, national or regional programmes (such as European Regional Development Fund (ERDF)[9], European Social Fund Plus (ESF+)[10], Just Transition Fund[11], LIFE[12], Innovation Fund[13], InvestEU[14]), where appropriate, as well as private funds or financial instruments. The ERDF focuses amongst others on the development and strengthening of regional and local research and innovation ecosystems and smart economic transformation, in line with regional/national smart specialisation strategies. It can support investment in research infrastructure, activities for applied research and innovation, including industrial research, experimental development and feasibility studies, building research and innovation capacities and uptake of advanced technologies and roll-out of innovative solutions from the Framework Programmes for research and innovation through the ERDF.

The EU's Recovery and Resilience Facility (RRF)[15] [currently available in all Member States] aims at financing projects that directly tackle the economic and social impacts from the Coronavirus crisis and support the green and digital transition. For project ideas that directly contribute to these objectives and that have a strong focus in one Member State it is advisable to check access to the RRF for a fast and targeted support.

In order to encourage multi-actors approaches and to be more effective in achieving impact, proposals are expected to synergize with other relevant initiatives funded at EU level, including the Knowledge and Innovation Communities (KICs) of the European Institute of Innovation and Technology (EIT)[16]. The innovation ecosystems created and nurtured by the EIT KICs can in particular contribute to building communities or platforms for coordination and support actions, sharing knowledge or disseminating and fostering the exploitation of the project results. Where relevant, and without prejudice to the direct participation of the EIT KICs in the R&I activities under this destination, proposals are encouraged to explore other forms and means of service provisions distinct from the EIT KICs that can be complementary

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9 https://ec.europa.eu/regional_policy/en/funding/erdf/

10 https://ec.europa.eu/esf/main.jsp?catId=62&langId=en

11 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/just-transition-mechanism/just-transition-funding-sources_en

12 https://ec.europa.eu/environment/archives/life/index.htm

13 https://ec.europa.eu/inea/en/innovation-fund

14 https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/investment-plan-europe-juncker-plan/whats-next-investeu-programme-2021-2027_en

15 https://ec.europa.eu/info/strategy/recovery-plan-europe_en

16 https://eit.europa.eu/our-communities/eit-innovation-communities

to the considered proposals and their activities. Collaboration with other innovation communities that can well support the project implementation and impact is also encouraged. Any such cooperation should be based on adequate intellectual property management strategies.

In line with RRF's requirement and the European Green Deal objectives, research and innovation activities should comply with the **'do no significant harm' principle**, as defined in Articles 3(b) and 17 of the EU Taxonomy Regulation[17] established to determine whether an economic activity is environmentally sustainable. Compliance with the 'do no significant harm' principle needs to be assessed both for activities carried out during the course of the project as well as the expected life cycle impact of the innovation at a commercialisation stage. The robustness of the compliance must be customised to the envisaged TRL of the project. In particular, the potential harm of Innovation Actions contributing to the European Green Deal will be monitored throughout the project duration. Horizon Europe projects will play an important role to help economic operators reach or go beyond the standards and thresholds set up in the Regulation as technical screening criteria and to keep them up-to-date. Alignment of research and innovation activities with EU Taxonomy technical screening criteria will also be piloted in selected topics with the aim to facilitate their later access to green finance to foster the market uptake of the innovative technologies and solutions they developed.

Horizon Europe's approach to **international cooperation** consist of multilateralism and purposeful openness, combined with targeted actions with key third-country partners. Actions focus on aligning national, European and global efforts and investments in research and innovation areas that contribute towards achieving key European Commission priorities. With regard to cluster 5, the Commission pushes the acceleration of clean energy innovation through the Mission Innovation[18] Initiative, which was launched at COP21 and currently comprises 24 countries and the European Commission. International cooperation of EU Member States and Associated Countries in the context of Mission Innovation in relevant topics in this work programme is encouraged. In addition, this work programme specifically addresses cooperation with African countries and cooperation on sustainable decarbonisation with major emitting countries around the world, in line with the spirit of the Paris Agreement which emphasises the need for global cooperation on technology development and transfer.

For topics in this cluster, consortia could consider their voluntary contribution in terms of data, indicators and knowledge to relevant **Joint Research Centre** (JRC) platforms for capitalising the knowledge developed in their projects and become more policy relevant:

- Life cycle assessment (LCA) and its relevant application to value chain assessment: European Platform on Life cycle assessment (EPLCA, https://eplca.jrc.ec.europa.eu/)

17 Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088

18 http://mission-innovation.net/our-work/innovation-challenges/

and making reference to the Environmental footprint method when applying LCA (https://ec.europa.eu/environment/eussd/smgp/index.htm);

- Raw materials: Raw materials information system (RMIS, https://rmis.jrc.ec.europa.eu/);
- Soil and soil related issues: European Soil Observatory (ESO, https://ec.europa.eu/jrc/en/eu-soil-observatory);
- The natural capital accounting: INCA platform (https://ec.europa.eu/eurostat/ecosystem-accounts).

For the purpose of technology monitoring and progress against the state-of-art and helping to indicate project contributions towards the targets of the European Commission's Green Deal all actions related to **hydrogen and fuel cells** funded under this work programme shall report directly or indirectly on an annual basis in a secure online data collection platform managed by the Clean Hydrogen Joint Undertaking and The European Commission during the course of Horizon Europe. The reporting shall consist of filling in the template questionnaire(s) relevant to the project content (and the technology development and TRL).

Destination – Climate sciences and responses for the transformation towards climate neutrality

Europe has been at the forefront of climate science and should retain its leadership position to support EU policies as well as international efforts for a global uptake of climate action in line with the Paris Agreement and the Sustainable Development Goals (SDGs), including biodiversity objectives. Advancing climate science and further broadening and deepening the knowledge base is essential to inform the societal transition towards a climate neutral and climate resilient society by 2050, as well as towards a more ambitious greenhouse gas reduction target by 2030. It will involve research that furthers our understanding of past, present and expected future changes in climate and its implications on ecosystems and society, closing knowledge gaps, and develops the tools that support policy coherence and the implementation of effective mitigation and adaptation solutions.

The activities implemented under this section will enable the transition to a climate-neutral and resilient society and economy through improving the knowledge of the Earth system and the ability to predict and project its changes under different natural and socio-economic drivers, including a better understanding of society's response and behavioural changes, and allowing a better estimation of the impacts of climate change and the design and evaluation of solutions and pathways for climate change mitigation and adaptation and related social transformation.

This Destination contributes directly to the Strategic Plan's **Key Strategic Orientation** D *"Making Europe the first digitally led circular, climate-neutral and sustainable economy through the transformation of its mobility, energy, construction and production systems"* and the **impact area** "Climate change mitigation and adaptation".

In line with the Strategic Plan, the overall **expected impact** of this Destination is to contribute to the *"Transition to a climate-neutral and resilient society and economy enabled through advanced climate science, pathways and responses to climate change (mitigation and adaptation) and behavioural transformations"*, notably through:

a. Advancing knowledge and providing solutions in the any of following areas:

- Earth system science;
- Pathways to climate neutrality;
- Climate change adaptation;
- Climate services;
- Social science for climate action; and
- Better understanding of climate-ecosystems interactions.

b. Contributing substantially to key international assessments such as those of the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Science-

Policy Platform on Biodiversity and Ecosystem Services (IPBES) or the European Environment Agency (e.g. European environment - state and outlook reports, SOER).

c. Strengthening the European Research Area on climate change.

d. Increasing the transparency, robustness, trustworthiness and practical usability of the knowledge base on climate change for use by policy makers, practitioners, other stakeholders and citizens.

Coordination and synergies should be fostered between activities supported under this destination and those under other destinations of cluster 5 and other clusters of Horizon Europe.

In particular, complementarities with cluster 4 and cluster 6 should be taken into account by planning for adequate resources for co-ordination and clustering activities. Following a systemic approach, this destination concentrates on activities related to climate science and modelling, whereas cluster 4 supports activities in the area of low-carbon and circular industry, and cluster 6 contributes to R&I on the implementation of climate change mitigation and adaptation solutions in the areas covered by cluster 6 (notably Intervention Area (IA) 1 on biodiversity and nature-based solutions (NBS), Earth observation, IA 4 on seas, oceans and inland waters…).

Coordination and synergies are also encouraged with the activities funded under the work programmes on the Horizon Europe Missions, in particular the Mission on Adaptation to climate change, the Mission on Climate neutral and smart cities and the Mission "Restore our Ocean and sea by 2030". While this destination supports upstream research activities on climate science, the Missions focus on the testing, demonstration and scale up of solutions to address the challenges of climate change and environmental degradation.

Actions should envisage clustering activities with other relevant ongoing and selected projects for cross-projects cooperation, consultations and joint activities on crosscutting issues and share of results, as well as participating in joint meetings and communication events. To this end, proposals should foresee a dedicated work package and/or task, and earmark the appropriate resources accordingly.

Where relevant, topics will be coordinated with the European Space Agency (ESA) activities to ensure that ESA scientific and observation assets nurture the future projects.

Earth system science

D1-1. 2023: Further climate knowledge through advanced technologies for analysing Earth Observation and Earth System Model data

Specific conditions

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: • If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).
Legal and financial set-up of the Grant Agreements	Beneficiaries will be subject to the following additional obligation regarding open science practices: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding under the action must be ensured through documentation, availability of model code and input data developed under the action.

Expected outcome:

Actions are expected to contribute to **all of the** following outcomes:

- New or improved models for climate predictions and projections, relevant for major international assessments like those of the IPCC.
- Support to the development of targeted and cost-efficient climate adaptation strategies in Europe.
- Advanced data science skills for high-performance computing, education and training.
- Lasting cooperation between Earth System research, Earth Observation data providers, Data science and high-performance computing (HPC) infrastructures.

Scope:

The EU and its Member States have invested massively in Earth Observation (EO), for example with the Copernicus Programme, in the Climate and Earth System Models (ESMs), and in their contribution to the implementation of GEOSS (Global Earth Observation System of Systems), which are yielding unprecedented volumes of data. This topic aims at spurring the exploitation of these assets, through advanced data technologies, including artificial intelligence and/or machine learning techniques or new statistical approaches based on the cooperation between data scientist, EO specialists and climate researchers.

Actions should create new insights in key processes of the Earth system and thus, improve climate predictions based on advanced exploitation of EO data and their appropriate integration in existing or new modelling approaches. The activities should also lead to improved evaluation tools to facilitate the analysis of new or improved ESMs and development of new process-oriented diagnostics to better understand remaining biases in models. The action should also distil more tailored, usable, and reliable information from models and observations for assessing risks caused by extreme weather and climate events in Europe in the coming decades.

Projects should build on the results of, and cooperate with, past and ongoing scientific research related to EO and ESMs as well as adaptation strategies at global and regional levels, e.g. the science base supporting the Copernicus Services, the relevant action within the GEO multiannual WP, as well as Destination Earth.

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[19]. In particular, beneficiaries are strongly encouraged to publish results data in open access databases and/or as annexes to publications. In addition, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding is expected.

D1-2. 2023: Climate-related tipping points

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

[19] FAIR (Findable, Accessible, Interoperable, Reusable).

Legal and financial set-up of the Grant Agreements	The rules are described in General Annex G. The following exceptions apply: Beneficiaries will be subject to the following additional obligation regarding open science practices: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding under the action must be ensured through documentation, availability of model code and input data developed under the action.

Expected outcome:

Actions are expected to contribute to all of the following outcomes:

- New or improved models for climate predictions and projections embedding the impact of climate and climate-related potential tipping points, relevant for major assessments like those of the IPCC and IPBES.
- Better understanding of potential cascading effects on climate and ecosystems as a consequence of reaching specific tipping points.
- Mitigation policies, taking into account the precautionary principle which is key with respect to human-induced crossing of Earth system tipping points.
- Adaptation strategies in most affected regions, globally, addressing the risks of crossing climatic tipping points and related ecosystem changes.

Scope:

Climate-induced tipping points are usually associated with singular catastrophic events of low probability but with very high impact. High probability tipping points, like for example those caused in the ocean by warming, acidification and deoxygenation, may have more fragmented and slow on-set impacts, but may add up to have heavy consequences at global dimensions. These tipping points in combination with gradual changes need to be addressed as seriously as singular catastrophic events, like the possible future collapse of the west-Antarctic ice sheet[20].

The ability and/or sensitivity of global Earth System Models (ESM) to simulate tipping point crossings and abrupt non-linear changes requires a systematic analysis of observations from past and present. The probability and impact of tipping point crossings and abrupt system changes need to be better quantified, for a sound risk analysis (including aspects of

[20] Heinze et. al., PNAS March 2, 2021 118 (9) e2008478118; https://doi.org/10.1073/pnas.2008478118

irreversibility), at scales relevant to processes like, ocean circulation, ecosystems processes, and human activities. Links with ecosystems changes need to be particularly addressed.

For detection of early warning signals for tipping points and to improve process understanding, statistical methods (based on paleoclimatic data) and other means should be applied. Also, methods as well as appropriate dissemination activities need to be created to determine and communicate resilience and safe operating space for humanity.

Projects should build on the results of and cooperate with, past and ongoing scientific research related to tipping points, abrupt ecosystems change and potential mitigation and adaptation strategies at global and regional levels.

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[21]. In particular, beneficiaries are strongly encouraged to publish results data in open access databases and/or as annexes to publications. In addition, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding is expected.

D1-3. 2023: Climate impacts of a hydrogen economy

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Procedure	The procedure is described in General Annex F. The following exceptions apply: • To ensure a balanced portfolio, grants will be awarded to applications not only in order of ranking but at least also to the proposal that is the highest ranked within the topic, provided that the application attain all thresholds.

[21] FAIR (Findable, Accessible, Interoperable, Reusable).

Expected outcome:

The objective of this topic is to achieve greater understanding among policy makers and stakeholders of the climate impact of large-scale deployment of hydrogen as an energy carrier, and options for addressing it. This will inform policy makers in the context of the European Green Deal, as well as alerting actors in the private sector to the environmental risks, opportunities and co-benefits associated with a hydrogen economy.

Actions are expected to contribute to **all of the** following outcomes:

- A rigorous assessment of the behaviour of hydrogen in the atmosphere.
- A rigorous assessment of the ways in which large-scale production, distribution and use of hydrogen as an energy carrier can affect anthropogenic radiative forcing.
- Better monitoring tools (methodologies and instruments) for detecting and quantifying hydrogen leakage (in situ or through remote sensing).

In each case, it will be necessary to consider direct and indirect radiative forcing, both from hydrogen (e.g. potential leakages) and from other forcers associated with, or displaced by, its production, its transport and consumption.

Scope:

Successful consortia should conduct **all of the** following activities:

- Develop a deeper and more precise understanding of the overall hydrogen cycle mechanisms and their future development under concentrations higher than historically observed (with a specific focus on hydrogen sink processes).
- Thorough analysis of the direct and indirect radiative forcing impacts of hydrogen, specifically by investigating the mechanistic interactions of hydrogen with tropospheric gases, in particular methane, carbon monoxide and water vapour.
- Assessment of **all of the** following aspects:
  - The potential systems, technologies and markets associated with large-scale hydrogen deployment.
  - The channels through which large-scale deployment of green hydrogen could reduce global warming (e.g. by displacing fossil fuels).
  - The channels through which large-scale deployment of hydrogen could contribute to global warming (e.g. through leakages in the supply chain, creation of a market for natural gas, indirect effects in the atmosphere, displacement of other low carbon technologies).

- Options for mitigating any global warming risks associated with hydrogen deployment (e.g. through leakage detection technologies).

Proposals are also invited to:

- Consider the extent to which the risks of climate impacts from hydrogen deployment vary between different uses (e.g. energy, industry, transport).
- Consider opportunities for mitigating such risks.
- Identify any significant non-climate co-benefits or side effects of hydrogen deployment (e.g. on air quality).

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[22]. In particular, beneficiaries are strongly encouraged to publish results data in open access databases and/or as annexes to publications. In addition, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding is expected.

D1-4. 2023: Improved knowledge in cloud-aerosol interaction

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: • If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other

[22] FAIR (Findable, Accessible, Interoperable, Reusable).

	data and services may additionally be used).
Legal and financial set-up of the Grant Agreements	The rules are described in General Annex G. The following exceptions apply: • Grants awarded under this topic will be linked to the specific grants awarded by ESA under the FutureEO programme. The respective options of the Model Grant Agreement will be applied. Beneficiaries will be subject to the following additional obligation regarding open science practices: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding under the action must be ensured through documentation, availability of model code and input data developed under the action.

Expected outcome:

This activity will enhance our understanding of the cloud-aerosol interactions and their impacts in the Earth system and develop advanced algorithms as well as high-resolution models to better reproduce realistic cloud structures, its interactions with different types of aerosols and their radiative impacts.

Project results are expected to contribute to **all of the** following outcomes:

- Enhanced large community effort in Europe to bring together the latest advances in science, modelling, in situ, ground-based and airborne remote sensing as well as satellite observations to tackle cloud-aerosol complex interactions.
- Improved Earth systems models and better climate prediction, in particular at seasonal and decadal time scales.
- Better understanding of convective systems leading to improved predictions of extremes event.
- Reduced uncertainties in climate models through a better representation of cloud formation, aerosol-cloud interaction, and their combined radiative properties.
- Use and assimilation of aerosol and cloud products from novel satellites (e.g. Earth Care) for climate and/or weather predictions.
- Contribution to IPCC in addressing this major knowledge gap in the Earth and climate system and important source of uncertainty in climate models.

Scope:

The challenge of this topic is to improve the representation of cloud formation, aerosol-cloud interactions and cloud vertical structures, and the radiative properties of the various cloud types that is the largest source of uncertainty in today's climate models and represent an important knowledge gap in Earth system and climate science, and in the Earth radiation budget in particular. This requires better understanding of multiple scattering of radiation within the three-dimensional structure of clouds and different direct and indirect effects of aerosols on radiative transfer. It will lead also to a strengthened understanding of mechanisms through which clouds and aerosols modify significantly the planetary albedo. The science of cloud formation and its impact on climate should be advanced through an integrated use of in situ and satellite observations in high-resolution models which reproduce realistic cloud structures its radiative properties.

The project will address this challenge through:

- Enhancing the systematic and coordinated collection and use of ground-based or airborne observing systems from relevant existing networks (e.g. Earlinet, Aeronet). These datasets will also be critical to enhance satellite retrievals and validation of cloud and aerosols parameters.

- Coordinating with the satellite community where needed, especially for supporting the validation needs of new missions such as ESA's EarthCARE.

- Establishing in the course of the projects wide-open access to the observation data needed with relevant measurement network databases (e.g. ACTRIS).

- Making use of new and existing in situ, ground-based remote sensing measurements and satellite data as well as exploiting dedicated and coordinated campaigns (ground-based, airborne) to advance the scientific understanding of the complex interactions between aerosols, clouds and climate at a fundamental level.

This topic is part of a coordination initiative between ESA and the EC on Earth System Science. Under the EC-ESA Earth System Science Initiative both institutions aim at coordinating efforts to support complementary collaborative projects, funded on the EC side through Horizon Europe and on the ESA side through the ESA FutureEO programme.

This initiative aims at funding a group of EC and ESA complementary projects pursuing a common objective through strong coordination and collaboration in the domain of Earth System Science and more specifically for this topic on improved knowledge in cloud-aerosol interactions.

Proposals should include a work package, means and resources for coordination with complementary projects funded under the ESA FutureEO initiative. The projects(s) should establish a close coordination and collaboration with the relevant ESA dedicated actions (ESA Atmosphere Science Cluster) to join advance towards enhanced observations, understanding and global and regional assessments of the cloud-aerosols interactions and the related atmospheric radiative heating and cooling processes and its impacts on the Earth and climate system.

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[23]. In particular, beneficiaries are strongly encouraged to publish results data in open access databases and/or as annexes to publications. In addition, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding is expected.

D1-5. 2024: Enhanced quantification and understanding of natural and anthropogenic methane emissions and sinks

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: • If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).
Legal and financial set-up of the Grant Agreements	The rules are described in General Annex G. The following exceptions apply: • Grants awarded under this topic will be linked to the specific grants awarded by ESA under the FutureEO programme. The respective options of the Model Grant Agreement will be

[23] FAIR (Findable, Accessible, Interoperable, Reusable).

	applied. Beneficiaries will be subject to the following additional obligation regarding open science practices: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding under the action must be ensured through documentation, availability of model code and input data developed under the action.

<u>Expected outcome</u>:

These activities will foster and enhance collaboration between the modelling and observing (satellite, ground-based, airborne) communities and advance towards an enhanced global and regional assessment of the methane sources and sinks, their short and long-term evolution as well as the related natural and anthropogenic processes and impacts on atmospheric chemistry and dynamics and on Earth radiation budgets. The expected outcomes hereafter are complying with the recommendations formulated by the user community during the ESA ATMOS-2021 conference[24].

Project results are expected to contribute to **all of the** following outcomes:

- A significant European effort to develop an enhanced capacity including extensive advanced in situ data, novel satellite observations and enhanced modelling efforts to quantify and understand natural and mainly anthropogenic methane emissions with unprecedented resolution in space and time.
- An increased coordination of in situ observations of methane emissions including enhancing communication and networking between the relevant observation communities.
- Enhanced science base in Europe to perform global and regional (European) scale high-resolution assessment of the methane sources and sinks, their short and long-term evolution, the related natural and anthropogenic sources and impacts on atmospheric chemistry and dynamics.
- Clear policy advice on current and future climate contributions of methane on global and regional (European) scale, including elaboration on effective mitigation options.
- Provision of a significant contribution to IPCC and related scientific efforts regarding methane emission similar to those of the Global Carbon Project.

[24] https://atmos2021.esa.int/

- Contribution to achieve the goals of the COP26 Glasgow agreement on methane emission reductions and to the EU methane strategy.

Scope:

The challenge of this topic is to quantify and understand natural and anthropogenic methane emissions with unprecedented resolution in space and time that should leverage the latest advances in observations from satellite, ground-based, and airborne, together with advances in reconciling inverse and bottom-up modelling approaches.

The project will address this challenge through:

- Deploying large coordinated in situ, ground-based and airborne observation monitoring campaigns over different Earth's ecosystems and anthropogenic sources (e.g. land fields, agriculture, farming, oil and gas industry) with different measurements approaches.

- Running these campaigns during an extended period of time, building on existing measurement infrastructures and initiatives, in order to support the validation of satellite products, but as well to support the development of new and enhancement of existing models and data assimilation techniques.

- Advancing towards an integrated methane observing system (on "facility scale") that capitalises on the latest advances in observations from satellite, in situ, ground-based remote sensing and airborne instruments as well as results from citizen science.

- Advancing the capacity of models and data assimilation techniques to specifically exploit novel medium and high-resolution satellite data? (e.g. GHGSat, PRISMA, Sentinel-2, Landsat-8/9, Worldview-3).

- Delivering inverse modelling to separate methane sources and sinks and to attribute inverse modelling estimated fluxes to specific processes building on sufficient spatial resolution to identify the origin, for instance, of large local emissions.

- Advancing towards an enhanced high-resolution global and regional assessment of the methane sources and sinks and its dynamics, the related natural and anthropogenic processes, and impacts on the Earth radiation budget.

This topic is part of a coordination initiative between ESA and the EC on Earth System Science. Under the EC-ESA Earth System Science Initiative both institutions aim at coordinating efforts to support complementary collaborative projects, funded on the EC side through Horizon Europe and on the ESA side through the FutureEO programme.

This initiative aims at funding a group of EC and ESA complementary projects pursuing a common objective through strong coordination and collaboration in the domain of Earth System Science and more specifically for this topic on enhanced quantification and understanding of natural and anthropogenic methane sources and sinks.

Proposals should include a work package to ensure coordination with complementary projects funded under the ESA FutureEO. Subjected to approval by ESA Member States, ESA will contribute to this effort by providing a dedicated Earth Observation satellite scientific component to complement, collaborate and coordinate with this activity. In particular, ESA will contribute with dedicated set of complementary scientific activities with special focus on exploring and exploiting the new capabilities offered by TROPOMI in combination with other relevant European and international satellite missions including novel very high-resolution observations.

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[25]. In particular, beneficiaries are strongly encouraged to publish results data in open access databases and/or as annexes to publications. In addition, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding is expected.

D1-6. 2024: Polar processes and the cryosphere

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: • If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).
Legal and financial set-up of the Grant	The rules are described in General Annex G. The following exceptions

[25] FAIR (Findable, Accessible, Interoperable, Reusable).

Agreements	apply: • Grants awarded under this topic will be linked to the specific grants awarded by ESA under the FutureEO programme. The respective options of the Model Grant Agreement will be applied. Beneficiaries will be subject to the following additional obligation regarding open science practices: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding under the action must be ensured through documentation, availability of model code and input data developed under the action.

Expected outcome:

Actions are expected to contribute to **all of the** following outcomes:

- Advance knowledge on conditions and processes, including climate-ecosystem interactions, relevant to international initiatives, such as the WCRP's Climate and Cryosphere Project.
- Support to the development and improvement of existing or new Climate or Earth system models used for international climate change assessments (e.g. CMIP models) and potentially also "digital twins" of the Destination Earth Initiative.
- Support to climate change adaptation strategies in cold regions.
- Support to the development of strategies to enhance the resilience of natural and built environments, supporting planning and adaptation to climate change.
- Contribution to the implementation of the European Green Deal and its climate objectives and the Arctic policy.

Scope:

Actions should improve scientific understanding in **only one** of the following areas:

a) Inland ice, including snow cover, glaciers and ice sheets and their interaction with climate change

The snow cover, ice sheets and glaciers affect not only the Earth radiation balance and the global climate, but also continental climate systems, the weather of circumpolar regions and their terrestrial and oceanic carbon dynamics, ecosystems and sea level.

The proposal(s) should address all of the following aspects:

- Observe, model, and predict the inland ice in a relevant region including the linkage with regional and global climate.
- Evaluate the risk of tipping points and multi-decadal reversibility or irreversibility in the climate system affecting inland ice.
- Assess the impact of changing land ice cover, volume and their variability on local/regional water cycle, ecosystems and economic supplies and services.
- If relevant, assess risks through release of pathogens (viruses, bacteria and other microorganisms...) and metals such as mercury.
- Quantify the contribution to sea level rise budgets and impacts caused by the melting of the inland ice.
- Evaluate the impact on ecosystems coverage and distribution, biological communities and human livelihood and cultures.
- Identify imminent, medium and long-term potential ecosystem shifts at regional scale.
- Provide data, tools and assessments relevant at regional and local scales to support climate change adaptation.
- Explore, identify and verify ecosystems management techniques to allow better adaptation and maintenance of ecosystem services in a changing land ice landscape.

International cooperation is encouraged, in particular with the United States of America, Canada, the People's Republic of China, Japan, the Russian Federation, South Korea, New Zealand, India, Singapore and Greenland.

Actions will build upon and cooperate with relevant Horizon 2020-funded projects, the EU Polar Cluster, relevant projects funded by the ESA Earth Observation Programme, the ESA FutureEO programme and ESA scientific mission, the Copernicus Climate Change Service and Copernicus Marine Environment Monitoring Service.

This topic is part of a coordination initiative between ESA and the European Commission on Earth system science. Under the EC-ESA Earth System Science Initiative, both institutions aim at coordinating efforts to support complementary collaborative projects, funded on the EC side through Horizon Europe and on the ESA side through the ESA FutureEO programme.

This initiative is intended to fund a group of ESA and EC complementary projects pursuing a common objective through strong coordination and collaboration in the domain of Earth System Science and more specifically for this topic on inland ice, including snow cover, glaciers and ice sheets and their interaction with climate change.

Proposals should include a work package and means and resources for coordination with complementary projects funded under the ESA FutureEO initiative. The project(s) should establish a close coordination and collaboration with the relevant ESA dedicated actions.

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[26]. In particular, beneficiaries are strongly encouraged to publish results data in open access databases and/or as annexes to publications. In addition, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding is expected.

b) Improving the understanding, measurement, projections, predictions and impacts of permafrost thaw

Observe, model and project terrestrial and coastal permafrost in a changing climate in Arctic and mountain regions, and in particular address all of the following aspects:

- Use available observations (from satellite and ground-based) to model and assess permafrost and its linkages and feedbacks with regional and global climate in the past and towards the end of this century.
- Improve the assessment of greenhouse gases release from thawing permafrost and its global impact.
- Identify and assess potential local or regional tipping points of natural systems.
- Improve the understanding of the impacts of permafrost thawing for the environment, for the indigenous populations and the local communities, including on water and food security, coastal erosion and infrastructures.
- Assess the impact, trends and new scenarios on ecosystem services, including exploring ecosystems management techniques with special attention to community or nature-based solutions.
- Assess release of pathogens (viruses, bacteria and other microorganisms...) and metals, and in particular, quantify the mercury and cadmium reservoir in permafrost.
- Ensure closer cooperation with the Arctic States, particularly Russia, in creating data and services for permafrost areas to improve environmental and health security and develop mitigation measures.

Actions should build upon and cooperate with relevant Horizon 2020-funded projects, such as the Nunataryuk[27] and Arctic PASSION[28] projects, the EU Polar Cluster, relevant projects

[26] FAIR (Findable, Accessible, Interoperable, Reusable).

[27] https://cordis.europa.eu/project/id/773421

funded by the ESA Earth Observation Programme, the ESA FutureEO programme and ESA scientific mission, the Copernicus Climate Change Service and Copernicus Marine Environment Monitoring Service.

This topic is part of a coordination initiative between ESA and the EC on Earth System Science. Under the EC-ESA Earth System Science Initiative, both institutions aim at coordinating efforts to support complementary collaborative projects, funded on the EC side through Horizon Europe and on the ESA side through the ESA FutureEO programme.

This initiative aims at funding a group of ESA and EC complementary projects pursuing a common objective through strong coordination and collaboration in the domain of Earth System Science and more specifically for this topic on inland ice, including snow cover, glaciers and ice sheets and their interaction with climate change.

Proposals should include a work package and means and resources for coordination with complementary projects funded under the ESA FutureEO initiative. The project(s) should establish a close coordination and collaboration with the relevant ESA dedicated actions.

International cooperation is encouraged, in particular with the United States of America, Canada, the People's Republic of China, Japan, the Russian Federation, South Korea, New Zealand, India, Singapore and Greenland.

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[29]. In particular, beneficiaries are strongly encouraged to publish results data in open access databases and/or as annexes to publications. In addition, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding is expected.

D1-7. 2024: Paleoclimate science for a better understanding of the long and short-term evolution of the Earth system

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

[28] https://cordis.europa.eu/project/id/101003472

[29] FAIR (Findable, Accessible, Interoperable, Reusable).

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Legal and financial set-up of the Grant Agreements	Beneficiaries will be subject to the following additional obligation regarding open science practices: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding under the action must be ensured through documentation, availability of model code and input data developed under the action.

Expected outcome:

The projects funded under this topic will assess climate variability building on past climate and environmental datasets.

Project results are expected to contribute to **all of the** following expected outcomes:

- Better process understanding, and reconstruction by Earth system models, of past changes in climate, their variability and interactions with ecosystems, leading to improved Earth system models based on paleo data.
- Definition of driving mechanisms and precise timing of the onset of glaciation and the switch from greenhouse to icehouse climates.
- Future climate changes scenarios produced in the light of documented past changes in climate and ice sheets, in particular warm climates/high sea level situations.
- Strengthened climate models, including ice-sheet, ocean, ecosystem and atmospheric components, enabling understanding of future climate.
- Identification of thresholds in Earth system components and feedbacks that may be responsible for non-linear behaviour of the climate system to external forcings.
- Review of indicators of abrupt changes, or early warning signals, and tipping points within the paleoclimate record.
- Synthesis of climate variations that will serve as fundamental bases for IPCC future assessment and benchmarks for model inter-comparisons.

Scope:

The geological and ice-core records provide the only long-term information existing on the conditions and processes that can drive physical, ecological and social systems during interglacial, deglaciation and abrupt climatic events. The challenge of the research to be conducted under this topic is to test climate/Earth system models over a large variety of possible climate scenarios, outside the range of variability recorded over the past centuries (i.e. to include the pre-/post-industrial transition).

This challenge will be tackled through the following activities:

- Aggregating high-resolution, well-dated, interoperable paleoclimatic databases on climate changes from the past (e.g. interglacials, deglaciation and abrupt events).Constrain the astronomical modelling and parameters on climate and sea-level changes, including for example from sedimentary sequences.

- Describing long and short-term climate evolution using paleoclimate data over various timescales of the Quaternary (last 2.6 million years) i.e. on decadal to geological timescales.

- Identification of climate tipping points, cascading effects, and environmental limits using paleo data.

- Documenting and quantifying the natural climate variability, in terms of amplitude and chronology.

- Allowing for consistent integration of large-scale and more regional/local factors to be reproduced by climate models using natural forcings.

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[30]. In particular, beneficiaries are strongly encouraged to publish results data in open access databases and/or as annexes to publications. In addition, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding is expected.

<u>**Climate change mitigation, pathways to climate neutrality**</u>

D1-8. 2024: Improved toolbox for evaluating the climate and environmental impacts of trade policies

Specific conditions	
Expected EU	The Commission estimates that an EU contribution of XX million would

[30] FAIR (Findable, Accessible, Interoperable, Reusable).

contribution per project	allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Procedure	*The procedure is described in General Annex F. The following exceptions apply:* • To ensure a balanced portfolio, grants will be awarded to applications not only in order of ranking but at least also to those that are the highest ranked within each area, provided that the applications attain all thresholds.

Expected outcome:

Project results are expected to contribute to **all of the** following outcomes:

- Enhance our knowledge and inform policy makers on the positive and negative impacts of trade and trade policy on the climate and, where relevant, also on the environment, in particular biodiversity, pollution and natural resources depletion.
- Improve and enlarge the toolbox of models and other research techniques as well as available data to analyse the impact of trade and trade policy on the climate.

Scope:

Actions must cover **all of the** following areas:

a) Study and quantification of the effects of trade on the climate and the environment

- In-depth study/quantification of technique and composition effects: in addition to the scale effect of increasing production, trade also has an impact on the sector composition of economies and the technologies used for production. The project(s) should quantify and decompose these effects, including their underlying mechanisms/causes.
- Projections of trade-related emissions in developing countries: it can be expected that most of future trade-related emissions will take place in developing countries. The project(s) should therefore estimate and quantify these future emissions under different scenarios, including the extent to which this is related to pollution offshoring and pollution haven effects.

- Clarify/quantify how much of trade-related emissions are actually induced by trade policy or would also happen without international trade: while trade-related emissions are an important part of total world emissions, not enough is known about the counterfactual, i.e. in the absence of international trade, how much of such emissions would still take place in the context of the domestic economy. The project(s) should estimate the net effect of trade.

- Study the effects stemming from changes in the use of resources attributable to international trade, both in terms of efficiency gains (e.g. in energy and material use) and in terms of changes in the climate impacts associated with production and consumption, and whether externalities are likely to be internalised. For specific sectors, the project should also look into emissions linked to the production in different countries versus transport emissions.

- Study the public perception vs. the reality of trade impacting on the environment and climate: while in the public debate trade is often associated with increased emissions related to the scale effect, technique and composition effects point to positive impacts in certain cases. The project(s) should study and compare public perception and reality of trade effects on emissions. Cases studies should include concrete examples of cases where public perception of trade effects on emissions and real effects diverge.

b) Study and quantification of the effects of <u>trade policy</u> on the climate and the environment

- In-depth study/quantification of trade creation and trade diversion affecting the climate: trade liberalisation affects trade flows through the diversion of such flows as well as inducing additional trade. The project(s) should study the net effect of these phenomena on the climate and the environment.

- Impact of environment/climate regulation on trade and competitiveness: it can be assumed that in some cases tightened environmental legislation can lead to compliance costs and competitiveness effects. It should be empirically studied to what extent this assumption is correct and to what extent the so-called "Brussels Effects" impacts these cost and competitiveness effects.

- What do the expansion of global value chains, offshoring and fragmentation (and their possible reversal) mean for the climate and climate-related trade policy: the project(s) should analyse the effectiveness of climate policy in such an international economic environment.

- The role of trade policy as a tool to address the free rider problems in climate and environmental policies: since addressing climate change is a global public good, free rider problems persist. To what extent can trade incentives help overcoming these?

- Effects of trade openness on environmental and climate policy: trade and international exchanges lead to the diffusion of technology and ideas. To what extent do these effects influence global climate and environmental policies?

c) Provision of related methodologies and toolbox

- Impact of trade and Foreign Direct Investment (FDI) on the productivity of sectors (do more productive sectors/producers tend to be cleaner?): the project(s) should endogenise (Global Trade Analysis Project GTAP) sector productivity to trade, including the separation of energy efficiency effects among the productivity effects.

- Impact of trade on land use (overall and composition), in particular on deforestation: the project(s) should study methodologies that can be used to better understand the effects of trade and trade policy on land use. Actions should also create/update a trade induced land use/land use change matrix for GTAP sectors.

- Transport-related pollution: the project(s) should create a transport mode matrix for GTAP sectors per countries.

- Enlarge/split the GTAP sectors list for emission-intensive sectors: the project(s) should create/improve the GTAP sector matrix for emission-intensive sectors.

Actions are also encouraged to explore synergies between the use of modelling approaches in international trade analysis and the use of comparable macroeconomic modelling in climate policy (for example, in Integrated Assessment Modelling).

International cooperation with research clusters, in particular in the United States, which have specific knowledge in the areas of this topic, is encouraged.

D1-9. 2023: Science for successful, high-integrity voluntary climate initiatives

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Eligibility conditions	The conditions are described in General Annex B. The following

	exceptions apply: • If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).

Expected outcome:

Projects results are expected to contribute to **all** of the following expected outcomes:

- Capacity building to help governments and non-state actors ensure higher-integrity in voluntary climate change mitigation initiatives through enhanced evaluation, design, implementation and monitoring.
- Helping to translate scientific consensus and knowledge (e.g. IPCC reports) and government commitments (e.g. under Paris Agreement), into meaningful corporate climate strategies and actions.
- Design of improved, better harmonised and more transparent rules, policies and verification schemes for voluntary climate initiatives, increasing incentives for uptake of best practices and reducing risks of greenwashing, including in the use of offsets.
- Better understanding the potential and implications of private sector investments into climate actions, including in the developing countries, from the point of view of global emissions reduction needs, their cost-effectiveness and implications for sustainable development.
- Identification of trustworthy sources of carbon credits and best-practice offsetting schemes responding to the needs of various end-users.
- Contribution to as the formulation of national, EU and global mitigation strategies and pathways.

Scope:

To increase the chances of reaching the goals of the Paris Agreement, global GHG emissions should reach "net-zero" by mid-century and be halved by 2030 compared to current levels. To achieve these goals, immediate, rapid and large-scale emissions reductions are needed across all sectors of the economy. Voluntary initiatives and pledges by non-state actors, such as the private sector, financial institutions, civil society, cities and subnational authorities, could help fill the ambition gap, mobilise finance and accelerate the transformation process, but the actual climate impact of these efforts must be better understood and their integrity-related concerns must be overcome. This includes compensation schemes through voluntary carbon markets (distinct from compliance programmes such as the EU Emission Trading System).

This action should contribute to the development and scaling of high-quality voluntary initiatives that deliver genuine climate benefits in Europe and globally. It is expected to advance the knowledge about the role of voluntary initiatives in achieving the objectives of the Paris Agreement and their compatibility and interactions with government commitments, regulated markets and between each other. It should address a range of barriers and weaknesses associated with voluntary initiatives, including inconsistency of definitions and claims (e.g. net-zero, carbon positive, carbon negative, climate neutral, etc.), their environmental integrity, limited data availability and associated transparency issues, fragmentation, complexity, as well as poor measurement, verification and reporting practices. It should tackle issues related to additionality, double counting, governance, and accounting of the wider social and ecological consequences. The action should also evaluate the potential role of (various types of) offsets in voluntary initiatives, and assess their feasibility and the implications for transition pathways. It should analyse the scientific integrity of various existing carbon offsetting schemes, identify their strengths and weaknesses and develop clear scientific guidance about the proper use of carbon credits as part of an overall push toward net-zero emissions, taking into account the needs of different categories of end-users (e.g. business, public institutions, individuals etc.). This should include analysis of how offsets affects and interact with other emission abatement options.

The action should also explore and assess different options for improved monitoring, reporting and verification of the effectiveness and integrity of various voluntary climate initiatives.

Finally, it should enhance the modelling tools to better integrate voluntary carbon initiatives into transition pathways analysis.

Synergies with projects resulting from the topic “Next-generation NDCs and low-emission climate-resilient transformation pathways to meet Paris Agreement goals” should be established in particular as regards defining “net-zero”/climate neutrality as well as with other relevant Horizon 2020/Horizon Europe projects.

Co-creation with relevant stakeholders in the private and public sectors is strongly recommended, including actors from developing countries.

Actions should envisage clustering activities with other relevant ongoing and selected projects for cross-projects cooperation, consultations and joint activities on crosscutting issues and share of results as well as participating in joint meetings and communication events. To this end, proposals should foresee a dedicated work package and/or task, and earmark the appropriate resources accordingly.

D1-10. 2024: Next generation low-emission, climate-resilient pathways and NDCs for Paris aligned future

Specific conditions

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Legal and financial set-up of the Grant Agreements	Beneficiaries will be subject to the following additional obligation regarding open science practices: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding under the action must be ensured through documentation, availability of model code and input data developed under the action.

Expected outcome:

Projects results are expected to contribute **to all of the** following expected outcomes:

- Improved transparency, consistency and clarity of GHG emission reduction commitments, making them more concrete and easier to evaluate and track.
- Production of more diversified, granular and customised state-of-the-art pathways consistent with the objectives of the Paris Agreement at global and national levels in a diverse selection of countries, better reflecting different national circumstances and constraints and promoting synergies between climate action and other policy objectives.
- Policy packages to unlock deep transformation towards net-zero, leveraging insights from social sciences and humanities.
- Enhanced national capacities for scientific analysis of strategies and policies that are aligned with the objectives of the Paris Agreement, in particular in the countries of the African Union.
- Improved knowledge base to inform the UNFCCC processes, including the design and revision of post-2030 NDCs and the Global Stocktake in 2028, as well as major international scientific assessments such as the IPCC and IPBES reports.

Scope:

As showcased by various independent assessments, the current Nationally Determined Contributions (NDCs) and climate policies fall short of reaching the long-term goals of the Paris Agreement. Strengthening is necessary to close both the ambition and implementation gaps and to align national climate action with global objectives, while simultaneously achieving the broader Sustainable Development Goals and social welfare. Moreover, while countries have put forward plans and announcements to reach "net-zero" targets, the plans are hard to compare due to varying definitions, ranging from "zero-carbon" to "net-zero CO2" and "net-zero greenhouse gases" whereas choosing different gases, different timescales and different aggregation methods can lead to very different climate outcomes. This indicates that many aspects of the global climate neutral economy are still not well understood and more rigour and clarity is needed to ensure their robustness.

Projects should contribute to strengthening of national climate policies, NDCs and long-term strategies, by developing next generation low-emission transformation pathways, fostering more holistic and more integrative approaches that promote synergies and minimise trade-offs between mitigation action and other policy objectives while accounting for the above-mentioned barriers.

Projects **should** tackle **all of the** followings issues:

- Define principles for high-integrity climate commitments and more streamlined review processes;
- Increase the understanding of the role of ecosystems, in particular land use, in NDCs and other commitments. It should address both their stated (quantified) and assumed (implicit) role (such as through bioenergy or negative emissions), differentiation between anthropogenic and natural effects, accounting approaches as well as the consistency of these with global models and pathways, identifying options for enhancing transparency and coherence;
- Enhance knowledge about the role of non-CO2 gases in meeting the temperature goals of the Paris Agreement including the implications for the transition pathways of countries and sectors;
- Improve the integration of climate impacts and risks in low-emission pathway analysis;
- Improve representation of policy choices and technological progress in transition models and assess whether breakthroughs in major markets are likely to deliver transformation in the rest of the world;
- Advance knowledge on adequacy and fairness of climate targets, taking into consideration alternative fairness approaches and how these issues could be reflected in actual deployment of global climate action. This should include, but not be limited to, the analysis of the role and effectiveness of international financial flows in delivering on climate goals together with identification of most impactful approaches;;

- Improve understanding of how corporate and non-state commitments could affect national/regional decarbonisation pathways, for example through their effect on global supply chains including from land use.

Actions can cover a set of regions or be focussed on a specific one and explore it in greater detail. However, in all cases consortia should include the ability to model global decarbonisation pathways.

International cooperation is encouraged. It is recommended to include participation from institutions based in countries of the African Union to build their capacities in transition pathway analysis and policy advice.

Synergies with projects resulting from the topic "***Science for successful, high-integrity voluntary climate action***" should be established in particular as regards the role of non-state voluntary climate initiatives in achieving the objectives of the Paris Agreement as well as with other relevant Horizon 2020/Horizon Europe projects.

This topic requires the effective contribution of SSH disciplines including ethics and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond model documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[31]. In particular, beneficiaries are strongly encouraged to publish data and results in open access databases and/or as annexes to publications.

D1-11. 2023: More economic pluralism in transition pathway analysis and feasibility of green growth in the context of the transformation towards climate neutrality

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

[31] FAIR (Findable, Accessible, Interoperable, Reusable).

Expected outcome:

Projects results are expected to contribute to **all of the** following expected outcomes:

- More comprehensive understanding of the implications of the “net-zero” transformation for other environmental thresholds in view of fostering synergies between climate action and other environmental goals, including resource availability for future generations.
- Assessment of the long term feasibility of decoupling economic growth from resource use and adverse environmental impacts in the context of the current global efforts to transition to carbon and then climate neutrality.
- A more diverse set of pathways towards net-zero, based on alternative economic, technological and societal futures and reflecting different perspectives from economics, social and natural sciences, and including exploration whether and how non-mainstream approaches could deliver different desirable results.
- Enhanced representation of 1) energy and material demands and their links to the macro-economy, 2) lifestyle changes, sufficiency measures and societal well-being in integrated assessment models.
- Representation of energy and material demands, and their links to the macro-economy. Development of knowledge for shaping synergistic policies towards net-zero and to inform future major international scientific assessments such as reports by IPCC and IPBES.

Scope:

So far, global economic growth (expressed in GDP terms) has been tightly coupled with rising GHG emissions, demand for energy, raw materials, land and other natural resources. There is an urgent need for a new paradigm that reconciles continued development of human societies with the maintenance of the Earth system in a resilient and stable state. Meeting the climate ambition of the Paris Agreement while simultaneously respecting other environmental constraints would require not only rapid reductions of emissions of greenhouse gases and other climate forcers, but also decoupling of economic output from material throughput. Actions should advance knowledge on the feasibility of such green growth and explore other alternative socio-economic paradigms that could inform the transition to climate neutrality, taking into consideration recent trends including those associated with the COVID pandemic. They should investigate the associated consequences for societal well-being and living standards and draw conclusions for NDCs and long-term strategies under the Paris Agreement. Projects are expected to incorporate these considerations in the integrated assessment modelling frameworks. Projects should look beyond the general concepts and explore the practical implications, benefits, barriers and feasibility to pursuing such alternative socio-economic approaches as a policy choice within the EU and beyond.

The projects **<u>should</u>** address **some of the** following issues:

- Explore the role of technological progress, innovation, digitalisation, shifts in societal values and other emerging/potential trends in shaping future socio-economic development, and assess their impacts on the achievement of climate and environmental policy objectives, notably biodiversity and resource conservation related.

- Advance the knowledge about the role and potential of lifestyle changes and sufficiency measures in the overall strategies towards climate neutrality and in the context of other environmental goals, improve their quantification and representation in modelling frameworks and explore the underlying social, institutional, infrastructural, regulatory and other conditions for scaling-up.

- Improve the understanding of the dynamics between energy, material and land demand, and economic growth and assess the feasibility of both green growth and alternative approaches and their capacity to deliver increased well-being. This can include assessing whether shifts within a GDP-based system, such as greater share of services and recognition of household labour in national statistics, affect the compatibility of economic growth with climate goals.

- Identify and explore the main barriers to adoption of alternatives to growth-based economic models. For example: How plausible is it for policymakers to address them? Are there real-world examples? Can a region such as Europe pursue alternative approaches unilaterally? What are the implications for social equity?

- Assess the relationship between continued economic growth and well-being, investigate alternative approaches to enhance well-being, and evaluate the well-being effects of measures to transform societies towards climate-neutrality.

- Investigate how alternative economic approaches could be explained to and accepted by citizens and businesses concerned about both the climate and their livelihoods/operating conditions. For example, which concrete day-to-day changes would be required? How would professions work? What dis/-incentives would firms face to compete, expand and innovate? What would be the impact on the living standard?

- Explore potential future growth paradigms in developing economies, following (or not) the dynamics of high-income countries.

Given that actions are allowed to flexibility to define the scope of their work, complementarity between the projects selected for funding will be taken into account in the evaluation process.

The projects are expected to take a truly interdisciplinary approach, leveraging natural, economic and other social sciences to inform policies capable of delivering on multiple environmental, economic and social objectives simultaneously while taking into account constraints related to feasibility and acceptance.

D1-12. 2024: Improving accessibility and impact of climate change scenarios, transition pathways and models

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcome:

Projects results are expected to contribute to **all** of the following expected outcomes:

- Improved relevance, adequacy and robustness of models based on increased transparency, customisation, and better integration of insights from other scientific domains, notably from the SSH domain.
- Enhanced uptake of knowledge on transition to climate neutrality in Europe by better tailoring it to the specific needs of various categories of end users and their capacity building.
- Increased and more effective use of climate change scenarios and pathways based on provision of tailor-made tools, trainings and services.
- New business-models that promote open-access to climate change scenario modelling.

Scope:

Actions should contribute to improving accessibility of climate change scenarios and models to address the increasing interest in exploring pathways to limit global warming from various end-user groups, with diverse expertise and needs. Besides policy makers and scientific community, other relevant audiences are, for example, sub-national and non-state actors, including finance and business sector, regional authorities and general public.

Projects should address **all of the** following aspects:

- Improvements in the scenario framework for climate change research to make it more useful and address the specific needs of a broad range of users (but not necessarily with a single model/tool), in particular those that have not been fully addressed with IAMs so far, for example financial sector, corporations, industrial actors, and other private sector representatives as well as the public sector, in particular at sub-national level.

- Development and carry-out of services to promote user-friendly access and proper use by non-specialist audiences, such as training courses.

- And increase the transparency and accessibility of the underlying tools by lowering their entry barriers.

Projects could choose to focus on a specific target audience and tailor their work accordingly. This will be taken into account in the evaluation process to ensure complementarity.

As regards transparency – this should include activities to move the existing research software into the open source domain, next to other efforts. In addition, when dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond model documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles. In particular, beneficiaries are strongly encouraged to publish data and results in open access databases and/or as annexes to publications.

Active participation of various categories of end-users is necessary for this topic. The proposed solutions should be tested and disseminated to relevant audiences.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

D1-13. 2024: The role of climate change foresight for primary and secondary raw materials supply

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.

Type of Action	RIA

Expected outcome:

The successful proposal will support the transition to a digital and low carbon society in the context of the European Green Deal with a particular emphasis on climate change and raw material value chains. In particular, it should contribute to **all of the** following expected outcomes:

- Short-, medium-, and long-term scenarios of changes in the type, origin and quantity of raw materials required for the twin transition.
- Projections for the changes to the greenhouse gas and energy footprint associated with the supply of primary and secondary raw materials with a view to facilitating their use in integrated assessment models.
- Models and data contributing to the development of the European Commission's Raw Materials Information System.
- Inputs to international scientific assessments such as reports by IPCC, the International Resource Panel and IPBES.

Scope:

Achieving enhanced digitalisation and a low carbon society will involve a change in the type and quantity of the raw materials required by the economy. This can result in geopolitical shifts in extraction and processing, as well as an increase in the extraction, processing, and recycling of many minerals and metals, including ones that have so far been only marginally important. Materials are likely to be extracted from increasingly lower grade ores and hostile environments, from mining wastes, as well as through recycling. Ceteris paribus, this would involve a general increase in the energy required to supply raw materials, as well as associated greenhouse gas emissions and changes in some other environmental impacts (such as related to transport and land take for mineral extraction and waste disposal). It will also involve changes in technologies, some of which not sufficiently well understood.

This action will improve knowledge concerning the options, and challenges, in the short, medium, and long-term associated with the provision of raw materials required for the twin transition with a focus on interlinkages with climate change.

Sectors, technologies and material value chains to be analysed will be selected on a justified basis. The project will analyse changes to the carbon footprint associated with supply options for a selection of key primary and secondary raw materials for short, medium and long-term time horizons. Options analysed will relate to raw materials likely to have large changes in supply due to the twin transition, with important geopolitical and technological changes in relation to climate and circularity.

The analyses shall build on established life cycle assessment and product environmental footprint requirements and contribute to their further development. Scenarios shall account for geo-political/site-specific changes in supply and technologies building on, as far as available, existing demand scenarios from EC modelling activities, and must take into account the relevant EU policies (Fit-for-55, carbon neutrality by 2050). Scenarios must account for the foreseen variation and innovation advances in extraction, processing, recovery, recycling and other technologies along the value chains, including changes to the energy mix involved.

The proposal will include the involvement of experts for the different technologies related to the primary and secondary raw material options selected as well as representatives of the integrated assessment modelling community.

This action will develop state-of-the-art knowledge (models and databases) in relation to climate change and the implications of different options associated with the twin transition and the related increases in supply of some raw materials.

The action will build on existing modelling work for the supply and demand of primary and secondary raw materials and expand them to reflect typical transition pathways.

The action will align to established requirements of existing methodological and data frameworks such as for life cycle assessment and product environmental footprint.

While focusing on selected technologies, conclusions should provide insights related to opportunities and challenges for sectors associated with the twin transition.

Stakeholders are to be selected on a justified basis to be consulted at key steps to provide informed feedback on the modelling, data and analyses.

Climate change impacts and adaptation

D1-15. 2023: Modelling for local resilience - Developments in support of local adaptation assessments and plans

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: • If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).

Expected outcome:

Projects results are expected to contribute to **all** of the following expected outcomes:

- Better informed adaptation plans and strategies at the regional and local level.
- Strengthen science-based decision-making when it comes to resilience and disaster risk management.
- Stronger local adaptive capacity.
- Improved synergies between national, regional and local Green Deal objectives, in particular adaptation action.
- Better coordinated and more impactful R&I activities on adaptation modelling and risk assessment.

Scope:

The EU strategy on adaptation to climate change[32] stresses the need to increase local resilience; as one of its key implementation actions the Horizon Europe Mission on Adaptation to Climate Change has been launched in September 2021 with the aim to support at least 150 European regions and communities to become climate resilient by 2030. Yet resources and tools to address adaptation at the local level are often scarce. To improve the support to local adaptation action it is essential to increase the availability, reliability and accessibility of climate information with increased spatial resolution.

Therefore actions should:

- Develop and test user-friendly high-resolution climate physical risk assessments models. This could include research on methods to increase resolution of global climate models and regional climate models that underpin risk assessment modelling.
- Consolidate information and data on cost and effectiveness of adaptation actions (including from FP7 and Horizon 2020) at local level. Carry out work to close the

[32] COM(2021) 82

remaining knowledge gaps. This should also feed into the knowledge basis of the Mission on Adaptation to climate change and be made available to all EU regions and communities. This work could include improvements in modelling and other relevant tools in this domain.

- Facilitate quick and operational guidance from adaptation, impact and risk modelling for decision-makers and other stakeholders, in particular to support the development of robust decision-making under uncertainty.
- Draw-up a roadmap of R&I priorities on adaptation and associated economic modelling, risk assessment and management tools towards a 2030-2035 timeframe.

The use of environmental observations and Earth systems models innovations funded by EU R&I programmes (FP7, Horizon 2020) is encouraged. This should include using data from the Copernicus Climate Change Services, and other relevant sources (such as GEOSS).

As much as possible the project should integrate the results of the existing studies and evidence-based research, namely from projects from topic HORIZON-MISS-2021-CLIMA-02-03 "Towards asset level modelling of climate risks and adaptation"33 and the Study on Adaptation Modelling for Policy Support[34].

Coordination is encouraged with the activities funded under the work programme of the Mission on Adaptation to climate change.

The participation of social sciences, especially economists, and humanities disciplines is encouraged to meet the outcomes of this topic.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

<u>Social science, citizen science and behavioural science for climate action</u>

D1-16. 2023: Solar Radiation Modification: governance of research

Specific conditions	
Expected EU	The Commission estimates that an EU contribution of XX million

[33] Funding & tenders (europa.eu)

[34] https://op.europa.eu/o/opportal-service/download-handler?identifier=cfa86c26-764e-11eb-9ac9-01aa75ed71a1&format=pdf&language=en&productionSystem=cellar&part=

contribution per project	would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	CSA
Procedure	The procedure is described in General Annex F.

Expected outcome:

The purpose of the action is to explore a hypothetical framework for the governance of experimental research in the area of solar radiation modification (SRM), defined as action to reduce solar radiative forcing through means other than through the reduction of net greenhouse gas emissions. The action should identify, on the basis of a comprehensive and balanced assessment, whether and how the governance of SRM field research could work in practice.

The IPCC 6th Assessment report (Working Group I contribution) concluded that SRM could offset some of the effects of anthropogenic warming on global and regional climate, especially if combined with emissions reductions, and with carbon dioxide removal, and phased out gradually. However, a number of risks are associated with its deployment, and the IPCC found that there is low confidence in our understanding of the climate response, especially at regional scales. At international level, its deployment is addressed (and largely prohibited) by the Convention of Biodiversity due to its potentially substantial negative effects on biodiversity. Nevertheless, the topic continues to draw interest, including from non-state actors, as the effects of climate change itself become more evident.

The action should therefore develop a possible governance framework for SRM experiments on a case-by-case basis, based on a balanced assessment of the best available scientific knowledge, as well as the perspectives of relevant stakeholders. It should also identify what the characteristics of such a governance framework should be, taking into account issues such as scientific rigour, risk assessment and public legitimacy.

Promotion of SRM or conducting of SRM field experiments is outside the scope of this call.

Scope:

In order to achieve the expected outcome, actions should include **all of the** following:

- Synthesis of the state of the art regarding the potential contribution of SRM to climate stabilisation, and its associated risks.

- Clarification of what activities constitute SRM, and the extent to which SRM is permitted, prohibited and/or governed within the ERA at present.
- Proposal of principles and guidelines that could be used by a public authority for permitting, prohibiting or supervising SRM field experiments on a case-by-case basis. Factors to consider could include inter alia:
    - Scientific and operational preconditions (e.g. monitoring mechanisms, time horizon, contingency planning).
    - Legal issues (e.g. liability for impacts).
    - Decision-making processes (e.g. Who gets to decide? Procedural aspects such as how to ensure broad, informed stakeholder consultation).
    - Approaches to cost-benefit analysis and risk assessment in a context of uncertainty (risk of action, and risk of inaction).
- An inclusive expert and stakeholder dialogue process should be organised in order to inform the analysis mentioned above.
- The action should build on existing and ongoing research as much as possible and collaborate with other international dialogues on SRM governance where appropriate.

The action is also encouraged to consider the following questions:

- Whether SRM field research under controlled conditions (e.g. within the ERA or like-minded jurisdictions) could lessen the risk of its unregulated deployment elsewhere in the world.
- Comparison of the risks of SRM with analogous risk management dilemmas faced by science and society (for example the release of genetically modified organisms).

D1-17. 2023: Behavioural change and governance for systemic transformations towards climate resilience

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.

Type of Action	RIA
Procedure	The procedure is described in General Annex F.

Expected outcome:

Projects are expected to contribute to **all of the** following outcomes:

- Decision-makers at local, regional, national and European level are able to more effectively scale up behavioural change for systemic transformations towards climate resilience, knowing more about relevant social tipping points, leverage points and governance in this context.
- Easier assessment of the potential of and progress in scaling up change in behaviour and for directing governance to achieving systemic transformations towards climate resilience.

Scope:

No matter how successful our efforts to mitigate further climate change will be, it is evident that already now significant climate impacts will be unavoidable and hence it is inevitable that one way or another we will have to adapt. The question is on what terms this adaptation will take place. With the new Strategy on Adaptation to Climate Change and the recently launched Mission on Adaptation to climate change on this issue, Europe has set out that the direction of this change will be systemic transformations towards just climate resilience, to be reached by 2050.

As nations, regions, cities and local communities are now developing their vision and pathways towards just climate resilience, increased importance is given to the role of behavioural change and governance in achieving the systemic transformations needed to regain resilience in a harsher climate future to events and hazards potentially attributable to climate change.

The objective of this topic is to reach a better understanding of and provide recommendations on how behavioural change could be scaled up and how governance would have to be improved to reach the goal of just climate resilience by 2050.

The role of individual or community behavioural change in this societal transformation is to be approached as embedded in changes of political and economic systems. Shifts from individual values and community behaviour need to be seen as integrated with societal changes in governance, implying a combination of cultural changes and shifting social norms, alongside interventions by institutions and through the market[35].

Within this scope, projects are requested to enhance the understanding of:

- Social tipping points and leverage points in climate adaptation: better understand the social acceptability of non-adaptive behaviours or how new adaptive behaviour would become widespread (social tipping points); better understand how a small shift in one part of a system would generate changes across the system as a whole (leverage points); understand how increasingly frequent extreme weather events (whether or not attributable to climate change) leads to changes of individual and social perceptions and behaviours, and how it leads to changes in local adaptation policies and actions.

- Features of good governance for systemic transformations to climate resilience: better understand features and structures of governance and institutions to ensure economically and socially just transformations appropriate for the local conditions, e.g. a fair distribution of costs and benefits of the transformations; better understand features and structures of governance and institutions that generate a high systemic adaptive capacity, e.g. the ability to effectively leverage public-private sector investment for adaptation actions.

- Conditions and capacities needed for systemic change: better understand the conditions and capacities that would allow individual behaviour to change the system so that the system further changes individual behaviour, e.g. access to relevant knowledge and information or opportunities to engage in decision-making.

Projects are encouraged to use the results of the Mission on Adaptation to Climate Change and experiences with Copernicus Climate Change as testbed to underpin their findings.

Finally, projects are requested to develop the following deliverables:

- Concrete recommendations of operational nature to those regions and communities that served as their case studies.

- General guidance for all other actors at national, regional, or communal level.

- A framework and indicators for assessing the potential of and progress in scaling up change in behaviour and for directing governance to achieving systemic transformations towards climate resilience.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

[35] Changing our ways? Behaviour change and the climate crisis, 2021, Report of the Cambridge Sustainability Commission on Scaling Behaviour Change.

D1-18. 2023: Improving the evidence base regarding the impact of education on sustainability- and climate change-related learning outcomes

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

<u>Expected outcomes:</u>

Project(s) are expected to contribute to **all of the** following expected outcomes:

- Methods to evaluate the impacts of education measures (including education policies, investments, education programmes, educators' training, etc.) in the field of learning for environmental sustainability and climate change.
- Development of an initial set of suitable indicators to monitor progress in implementing such education measures.
- Mapping of policy evaluation methods, monitoring frames and indicators in the area of sustainability and climate change education, in EU Member States and internationally, with the objective to identify best practices and reproducible solutions. This includes evaluation and assessment of impacts through large-scale testing (including international assessments, such as PISA, TIMSS, PIRLS), project-based monitoring/assessment, surveys, etc.
- Definition of suitable areas for assessment of the impact of education policies/interventions (e.g. skills/competence measurement of learners, educators; investment in green education; link between education and engagement in sustainability and climate action; effective communication strategies; training of professionals).
- Developing a comprehensive assessment model on the basis of a wide range of indicators (e.g. capturing commitments, implementation and results).
- Developing a methodology tailored for conducting impact assessments and evaluations of policies on learning for environmental sustainability (taking into

account inputs, processes, context, outcomes), addressed to and adaptable to different education and training levels in a life-long learning context (i.e. early childhood education and care, school, Vocational Education and Training (VET) and higher education, non-formal learning).

- Running of minimum 2 case studies using the developed methodology.

Scope:

The EU Green Deal, the Communication on the European Education Area, the Biodiversity Strategy for 2030 and other key EU initiatives highlight the importance of education and training to achieve an environmentally sustainable, just and climate-neutral economy and society. As emphasised in the EU Green Deal Communication, schools, training institutions and universities are well positioned to engage with pupils, parents and the wider community on the changes needed for a successful transition to a green economy. Education is instrumental to enable citizens to act on climate change and to change behaviours towards more sustainable patterns. The green transition, together with the digital transition, has also become a key policy priority in the Recovery and Resilience Plans. At the same time, the dimension of "sustainability and greening of education and training systems" is still relatively new in the EU context, and research is needed to understand the impact of sustainability and climate change education on what learners actually learn and how this influences mindset and actions related to sustainability at the individual and collective level.

The Commission has proposed in 2022 to the Council a Recommendation on learning for environmental sustainability[36] which outlines the main policy lines to place sustainability at the core of education and training. It has also developed a European sustainability competence framework[37], defining the knowledge, skills, attitudes needed to address challenges related to sustainability, including climate change[38].

Measuring impact and implementation of learning for environmental sustainability is essential. Such monitoring helps to ensure that policy and programmes remain relevant and effective. Monitoring will also help planning and reorienting curricula and programmes, increase understanding of progress achieved, improve decision-making and contribute to peer-learning among stakeholders.

It is essential to measure the impact of learning in the field of sustainability, directed at learning outcomes, including knowledge, skills and attitudes that learners develop with regard to sustainability. Such monitoring can help strengthen and adjust policies, learning processes and practices to further improve learning outcomes and ultimately contribute to sustainable living. However, current monitoring processes in the area of learning for environmental

[36] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2022:11:FIN

[37] https://publications.jrc.ec.europa.eu/repository/handle/JRC128040

[38] EU Green Deal call LC-GD-10-3-2020 subtopic 1: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/lc-gd-10-3-2020

sustainability are mainly input-oriented; inputs, including policies, programmes and curricula, teacher training, are obviously related to learning outcomes, but cannot be equated with those inputs.

Learning outcomes relate to what learners know and can do after a “learning intervention”, usually after an extended period of time (like a study programme). Learning interventions themselves depend on a range of inputs (inducing investments, policies, curricula design). Learning outcomes are usually described as knowledge, skills and attitudes that learners have developed in a specific area. Regarding learning for environmental sustainability, it is crucial to better understand which interventions and measures are effective to produce intended but also novel learning outcomes needed for the green transition of our society and economy. This necessitates a deeper analysis and assessment of the impact such learning has on learners at the individual and collective level.

Addressing both inputs and outcomes and the processes that link them is key. This also includes taking into account contextual factors - both education-related and non-educational - that might influence learning outcomes. To capture the lifelong learning scope and ambition of learning for environmental sustainability, it will also be important to widen the current focus of monitoring pupils and students (mainly at secondary level) to both younger and older generations. Moving beyond formal learning and even beyond education to measuring impact in the wider economy and society requires more research, as well as innovation.

Methods that address impact assessment of learning outcomes should therefore be directed at different levels (school, education system, EU-wide). Such models require taking into account commitment (e.g. legislation, policy measures, top-level strategies and action plans), context (governance, structure of education system) implementation (e.g. funding, governance, curricula, teacher training) and results (e.g. learning outcomes in terms of skills and competences, sustainable infrastructure).

The specific scope and approaches to learning for environmental sustainability can pose particular challenges to measuring the impact it can have at individual and collective level. For example, education that fosters strong links with the local community and is highly contextual, will be difficult to compare at regional, national or international level. Interdisciplinary, hands-on and socio-emotional approaches to learning and teaching do not necessarily align with test-based student assessment, which often serves to monitor and measure impact and progress in the area.

Effectively evaluating novel concepts and competences such as exploratory and futures thinking that encourage learners to imagine and create what does not yet exist, is very difficult with pre-defined targets and indicators. Therefore, holistic, multipronged approaches, including suitable indicators on sustainable and climate change education and training, appear to best suit the broad scope and ambitions in this area, monitor progress and guide policy making at national and European level.

Initiatives should take into account the work developed during the UN Decade in Education for Sustainable Development (DESD) and the Global Action Programme for Sustainable

Development (GAP), which include a “Global Monitoring and Evaluation Framework” relying on questionnaires, research reports, stakeholder engagement, self-reporting, as well as other relevant research. Similarly, system-wide assessment through large-scale programmes like PISA, TIMSS or PIRLS play an important role in education monitoring across the EU. More recently, large-scale assessments are addressing learning for sustainability, highlighting, for example, the correlation between awareness on environmental and climate challenges and pessimism (PISA). However, according to research, there is a certain tension between what international large-scale assessments measure and socio-emotional, hands-on or place-based learning for environmental sustainability.

To capture the lifelong learning scope and ambition of learning for environmental sustainability, it will also be important to widen the current focus of monitoring pupils and students (mainly at secondary level) to both younger and older generations. Moving beyond formal learning and even beyond education to measuring impact in the wider economy and society requires more research, as well as innovation.

Actions should envisage clustering activities with relevant projects and initiatives, such as the two Horizon 2020 projects ECF4CLIM and GreenSCENT, the GreenComp, the European sustainability competence framework developed by the JRC) for cross-projects cooperation, consultations and joint activities on crosscutting issues, to share their results, as well as to participate in joint meetings and communication events. To this end, proposals should foresee a dedicated work package and/or task, and earmark the appropriate resources accordingly.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

Climate-ecosystem interactions

D1-19. 2024: Quantification of the role of key terrestrial carbon ecosystems on the carbon cycle and related climate effects

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.

Type of Action	RIA
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: • If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).
Legal and financial set-up of the Grant Agreements	The rules are described in General Annex G. The following exceptions apply: • Grants awarded under this topic will be linked to the specific grants awarded by ESA under the Future EO programme. The respective options of the Model Grant Agreement will be applied.

<u>Expected outcome</u>:

A multidisciplinary assessment and quantification of the role of terrestrial ecosystem dynamics (including land use, land use change and forestry) in the carbon cycle, building on dedicated in situ data collection, novel satellite data development, and advanced carbon and terrestrial ecosystem models.

Project results are expected to contribute to **all of the** following outcomes:

- Improved methods for key ecosystems state monitoring in Europe, regarding terrestrial carbon, including e.g. forestry, croplands, peatlands, extensive grasslands, tundra and mangroves, and tackling e.g. age-structure, species richness, canopy structure (including use of TLS), observations of wood density, hydrology and observations of biological volatile organic compounds, CO_2, CH_4, N_2O black carbon/particulates emissions.

- Advanced models targeting a realistic representation of ecosystem processes at model resolution that is compatible with policy implementation needs and with a structural approach that maximises compatibility and consistency with both in situ and new satellite observations.

- Improved handling of anthropogenic management practices (land use including forestry) in terrestrial carbon modelling, including lateral transfers of carbon (notably in the form of harvested biomass including exports, imports and use).

- Enhancement of carbon and land surface models by building on new information that will be available from novel and multiple satellites (new data assimilation schemes and observation operators).

- Improved modelling of dynamics and response of vegetation over time. This includes responses to and impacts of climate/natural extremes (wind throw, drought, pest outbreaks, fire), and the impacts of anthropogenic disturbance including degradation and behaviour and recovery of forest post-disturbance.

- Improved consistency between atmospheric inversions building on in-situ and satellite observation, flux measurements, and national and global statistics.

- Assessment of the consistency of observation and advanced models multiple through benchmarking activities at multiple scales including point measurements, and satellite observations at multiple temporal and spatial resolutions.

Scope:

The main challenge of this topic is to develop an enhanced capacity to better characterise the terrestrial carbon cycle of key European ecosystems as a function of anthropogenic emissions, environmental forcing conditions, and management practices at spatial resolutions required to represent the mechanisms by which interventions by man to move towards net-zero carbon balance can be quantified. Further, the dynamics and response of vegetation to climate and extreme events, short- and long-term stress, and natural dynamics e.g. fire, especially change in frequency, form and severity need to be better understood and quantified.

Proposals will address the following challenges:

- Enhance understanding and characterisation of the terrestrial carbon pools and fluxes with unprecedented accuracies and spatial scales taking advantage of the advent of a new generation of satellite missions (e.g., ESA's BIOMASS, FLEX, Sentinel missions, NASA's NISAR, JEDI, etc…) that will radically change the way we can observe the terrestrial carbon cycle.

- Through a coordinated European effort to expand dedicated campaigns to collect in situ data on land cover, land use and related changes.

- Advances in land surface and carbon modelling supported by high-performance computing capacity, allowing models to be run at unprecedented resolutions and accuracy. The emphasis shall be on consistency across spatial and temporal resolutions and with satellite observation processes.

- Extending and complementing satellite observations with elements linked to the LUCAS survey of Eurostat, EU Soil Observatory (EUSO) initiatives to develop integrated soil monitoring systems and research infrastructure e.g. ICOS, as well as coordination with Earth observation efforts (spectral signature characterisation, biophysical and biogeochemical observations commensurate with satellite resolutions, aircraft/UAV campaigns).

- Specific efforts to develop carbon and land surface models to be consistent with satellite observation e.g. above ground biomass, soil moisture, solar induced fluorescence, disturbance dynamics e.g. fire, and inclusion of additional key processes (coupling of Nitrogen and Phosphorus cycles, CO_2 fertilisation, carbon/water coupling, new modelling schemes to assimilate photosynthesis rates for direct GPP estimation).

- A significant coordination effort and collaboration with the relevant activities of major international scientific groups (e.g., IPCC, GCP) and ESA Carbon Science Cluster.

This topic is part of a coordination initiative between ESA and the EC on Earth System Science. Under the EC-ESA Earth System Science Initiative both institutions aim at coordinating efforts to support complementary collaborative projects, funded on the EC side through Horizon Europe and on the ESA side through the ESA FutureEO programme.

This initiative aims at funding a group of ESA and EC complementary projects pursuing a common objective through strong coordination and collaboration in the domain of Earth System Science and more specifically for this topic on the enhanced assessment and understanding of the terrestrial carbon cycle.

Proposals will include a work package to ensure coordination with complementary projects funded under the ESA FutureEO programme. In particular, ESA supports the development and access to novel space assets such as the new products from ESA scientific missions, ESA science and research results and datasets, and open science infrastructure, through the Carbon Science Cluster and related projects. Subject to approval by ESA Member States, ESA will complement this EC call with a major dedicated scientific action (as part of the ESA Carbon Science Cluster) to advance the required Earth Observations component.

<u>International cooperation</u>

D1-20. 2023: Needs-based adaptation to climate change in Africa

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: • Consortia must include 3 partners based in at least 2 different sub-Saharan African countries. • If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).
Procedure	The procedure is described in General Annex F.

Expected outcome:

Project results are expected to contribute to **all** of the following expected outcomes:

- Stronger adaptive capacity and climate resilience in Africa, with a focus on the Sub-Saharan region.
- Better informed climate adaptation policy response and capacity building on climate resilience in Sub-Saharan Africa, contributing to the objectives of the Africa-EU partnership.
- Improved synergies between adaptation action and other policy objectives, notably the Sustainable Development Goals agenda.
- Contribution to the international dimension of the EU Adaptation Strategy and to the Africa-EU Partnership.
- Knowledge base to underpin major international scientific assessments such as the IPCC Assessment Reports.

Scope:

The African continent is on the frontline of the climate emergency, it is highly vulnerable and adaptation to both present and future impacts of climate change is urgent and crucial to secure its long-term resilience and prosperity, in particular in the aftermath of the COVID crisis. While the demand for high-quality, actionable climate information and services is growing, there is a need for more holistic, better connected, more interactive and more user-oriented approaches across the entire adaptation value chain from knowledge production to users. This ranges from improved knowledge base, through increased accessibility, up to enhanced uptake of information and climate services by end-users spanning policy makers, governmental agencies, local authorities, civil society and the private sector. The focus of this topic is on countries in Sub-Saharan Africa.

Actions should:

- Improve the understanding of current and future climate related threats (and opportunities) in Africa, extending into sectors/domains that are underexplored from climate-risk perspective and including dynamics between climate and political/economic risks such as migration, food security and urbanisation patterns. Actions may address improvements in accuracy and skill of forecasts/projections.
- Identify key adaptation challenges, needs and gaps in the broader socio-economic context, including intersection with COVID-19-related trends and developments.
- Enhance planning, implementation and evaluation of climate adaptation strategies and measures and the understanding of their socio-economic benefits.
- Develop and test climate services/tools that bridge the gap between information availability and uptake by end-users in different sectors, including through capacity building and addressing issues such as access, uncertainty, trust, risk perception and management, and other barriers. Actions should also promote better understanding and enhanced cooperation between various actors such as regional climate centres, national meteorological services, intermediaries and end-users. Direct participation of relevant entities in the projects is strongly encouraged.
- Advance knowledge on value assessment of climate services and apply it to the services developed within projects.

Projects may focus on a specific country/region in Sub-Saharan Africa for more customised activities, but should evaluate and disseminate information on the broader relevance of their outcomes and options for replication in other locations.

Actions should pursue active engagement and consultation with relevant stakeholders such as African government agencies, civil society organisations and citizen groups to harness local knowledge and to better account for end-user needs. This should include research on co-production of climate information and user engagement models themselves to define which approaches are most suitable for adaptation purposes.

Actions should make use of the latest socio-economic, geophysical and other relevant data, leveraging by rapid progress in digital technologies. This should include observational data from the Copernicus part of the EU Space Programme and other relevant sources (such as in the context of GEOSS Global Earth Observation System of Systems).

Actions should also take into consideration the results of relevant Horizon 2020 projects, such as FOCUS-Africa, Down2Earth, CONFER or HABITABLE, in view of progressing the state of the art and taking the already developed services/tools to the next level.

In line with the Strategy for EU international cooperation in research and innovation (COM(2021) 252), international cooperation is encouraged and projects should aim at comprehensive involvement of African researchers and organisations, in view of maximising the impact and relevance of the projects.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities. The SSH contribution should embrace gender issues.

D1-21. 2023: EU-China Climate Change and Biodiversity Research Flagship - Pathways to carbon neutrality: focusing on decarbonisation, energy efficiency and socio-economic implications of the transition

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply:
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: • The following additional eligibility criteria apply: The proposals must use the multi-actor approach. See definition of the multi-actor approach in the introduction to this work programme part.
Procedure	The procedure is described in General Annex F. The following exceptions apply:

	• Grants awarded under this topic will be coordinated with the Ministry of Science and Technology of the People's Republic of China (MOST).
Legal and financial set-up of the Grant Agreements	The rules are described in General Annex G. The following exceptions apply: • Grants awarded under this topic will be linked to the specific grants awarded by the Ministry of Science and Technology, China (MOST) to the Chinese partners. The respective options of the Model Grant Agreement will be applied. Beneficiaries will be subject to the following additional obligation regarding open science practices: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding under the action must be ensured through documentation, availability of model code and input data developed under the action.

Expected outcome:

The EU and China have committed to become climate neutral (by 2050) and carbon neutral (by 2060), respectively. Successful proposal(s) will support the transition to a climate neutral and resilient society as part of the EU-China Climate Change and Biodiversity Research Flagship (CCB Flagship). Actions are expected to contribute to **all of the** following outcomes:

- Improve knowledge and mutual learning in both regions concerning potential pathways towards these stated climate goals.
- Identify, explore and present possible options and challenges in the short, medium and long-term that are necessary to achieve these goals.
- This topic should be achieved through a combination of state of the art modelling and dialogue between relevant experts.

Scope:

The topic aims at developing a state-of-the-art framework that includes up-to-date representation of technologies and policies for modelling different pathways that lead to climate neutrality from a holistic and sectoral perspective. Successful proposal(s) should include joint work by European and Chinese experts aimed at informing the achievement of each country's long-term decarbonisation goal. Actions under this call should consider deep reductions and pathways to net zero incorporating mitigation of both CO_2 and other greenhouse gases.

Actions should focus on **all of the** following main areas (the individual bullets are indicative suggestions for focus within each area):

a) Decarbonisation

- Knowledge concerning the policies needed to ensure the transformation of the energy and transport sectors from fossil fuel-based to net-zero carbon emitters.
- Opportunities for decarbonisation of industry and agriculture, for reducing net emissions related to land use, and for mitigation of non-CO_2 greenhouse gases.
- Transformation of energy and transport infrastructure to accommodate zero-carbon technologies and smart demand.
- CCUS technology to improve the efficacy of CO_2 capture in industry, and help to ensure sustainable, secure and affordable energy.

b) Energy efficiency

- Improving energy efficiency, including through electrification in industrial processes, transport and heating systems.
- Improving energy efficiency in buildings (including through improved design and construction, retrofitting, establishing or improving energy management systems).

c) Socio-economic implications

- Socio-economic challenges and opportunities in the transition to climate neutrality, including the transformation of the labour market and the distributional repercussions for different sectors, social groups and regions.
- Consequences of the green transition for human welfare, including on health.
- Opportunities and challenges related to consumer behaviour and lifestyle changes (e.g. consumer choices, changes in ways of living and working).
- Global implications of EU and China decarbonisation (e.g. through trade and commodity markets, impacts on climate action in third countries).

d) Dissemination and stakeholder engagement

- Strong component of engagement with public and private sector stakeholders in both regions, in particular with groups whose actions will be key to implementing and achieving the transition

Interactions with other actions developed under the EU-China Climate Change and Biodiversity Research Flagship and/or the Flagship on Food, Agriculture and Biotechnologies are encouraged.

The envisaged knowledge relates only to policy, modelling and pathways definition and planning. Development of specific technologies are out of the scope of this topic.

Actions should:

- Build on existing modelling work in both regions that has identified credible pathways to net zero emissions, continuing to develop and refine such pathways.
- Ensure that EU and China pathways fit into a consistent global framework (e.g. in terms of global carbon budget and use of scarce commodities).
- Focus on key milestones and enabling conditions needed in the short-term (e.g. by 2030, 2035) and medium-term (e.g. by 2040) to achieve each region's net zero goals. Such milestones and conditions are not limited to emissions levels, but can include technological, regulatory, market penetration and socio-economic developments.
- Feature a combination of integrated assessment modelling (to demonstrate that pathways are coherent and comprehensive) and other more granular techniques to explore specific transformation options in detail.
- Include stakeholder engagement activities aimed at linking the vision set out in pathways with the actions needed to achieve them (e.g. How mature does a certain technology have to be by when? Is this achievable?).

When dealing with models, actions should promote the highest standards of transparency and openness, as much as possible going well beyond documentation and extending to aspects such as assumptions, code and data that is managed in compliance with the FAIR principles[39]. In particular, beneficiaries are strongly encouraged to publish results data in open access databases and/or as annexes to publications. In addition, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding is expected.

D1-22. 2023: Placeholder EU-China Climate Change and Biodiversity Research Flagship - Blue carbon

Specific conditions	
Expected EU	The Commission estimates that an EU contribution of XX million

[39] FAIR (Findable, Accessible, Interoperable, Reusable).

contribution per project	would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply:
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: • The following additional eligibility criteria apply: The proposals must use the multi-actor approach. See definition of the multi-actor approach in the introduction to this work programme part.
Procedure	The procedure is described in General Annex F. The following exceptions apply: • Grants awarded under this topic will be coordinated with the Ministry of Science and Technology of the People's Republic of China (MOST).
Legal and financial set-up of the Grant Agreements	The rules are described in General Annex G. The following exceptions: • Grants awarded under this topic will be linked to the specific grants awarded by the Ministry of Science and Technology, China (MOST) to the Chinese partners. The respective options of the Model Grant Agreement will be applied. Beneficiaries will be subject to the following additional obligation regarding open science practices: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding under the action must be ensured through documentation, availability of model code and input data developed under the action.

Expected outcome:

Under this topic, blue carbon is understood as coastal marine ecosystems such as seagrass, saltmarshes and mangroves.

Actions are expected to contribute to **all of the** following outcomes:

- An understanding of how blue carbon in coastal waters of EU countries and the People's Republic of China contributes to greenhouse gases in the atmosphere.
- A quantification of how human activity in managing, destroying or regenerating blue carbon affects its emissions and sequestration of greenhouse gases.
- Measurement techniques for calibration, validation and monitoring blue carbon sequestration and emissions.
- A contribution to the European Commission's 2021 proposal to amend the Land Use Land Use Change and Forestry Regulation to include a commitment to assess the potential of including emissions and sequestration from the marine environment by 2035.
- A roadmap for including blue carbon in reporting to the United Nations Framework Convention on Climate Change (UNFCCC).
- A preliminary estimate of the actual and potential contribution of blue carbon to the greenhouse gas balance of the EU and the People's Republic of China.

Scope:

The project(s) should:

- Classify the main parameters that affect emissions and sequestration.
- Develop and test methods for measuring emissions and sequestration.
- Propose and test a portfolio of methods for managing blue carbon to increase sequestration.
- Cover representative sample sites on coasts in all European seas (Atlantic, Baltic, Black Sea, Mediterranean and North Sea) and Chinese seas.
- Engage with international bodies and researchers tackling the same issue.

Interaction with other actions developed under the EU-China Climate Change and Biodiversity Research Flagship and/or the Flagship on Food, Agriculture and Biotechnologies are encouraged.

International cooperation is encouraged, in particular but not exclusively with the People's Republic of China.

Destination – Cross-sectoral solutions for the climate transition

This Destination covers thematic areas which are cross-cutting by nature and can provide key solutions for climate, energy and mobility applications. In line with the scope of cluster 5 such areas are batteries, hydrogen, communities and cities, early-stage breakthrough technologies as well as citizen engagement. Although these areas are very distinct in terms of challenges, stakeholder communities and expected impacts, they have their cross-cutting nature as a unifying feature and are therefore grouped together under this Destination.

This Destination contributes to the following Strategic Plan's **Key Strategic Orientations (KSO)**:

- *C: Making Europe the first digitally enabled circular, climate-neutral and sustainable economy through the transformation of its mobility, energy, construction and production systems;*
- *A: Promoting an open strategic autonomy*[40] *by leading the development of key digital, enabling and emerging technologies, sectors and value chains to accelerate and steer the digital and green transitions through human-centred technologies and innovations;*
- *D: Creating a more resilient, inclusive and democratic European society, prepared and responsive to threats and disasters, addressing inequalities and providing high-quality health care, and empowering all citizens to act in the green and digital transitions.*

It covers the following **impact areas**:

- Industrial leadership in key and emerging technologies that work for people
- Affordable and clean energy
- Smart and sustainable transport

The **expected impact**, in line with the Strategic Plan, is to contribute to the *"Clean and sustainable transition of the energy and transport sectors towards climate neutrality facilitated by innovative cross-cutting solutions"*, notably through:

a. Nurturing a world-class European research and innovation eco-system on **batteries** along the value chain based on sustainable pathways. It includes improvement of technological performance to increase application user attractiveness (in particular in terms of safety, cost, user convenience, fast charging and environmental footprint), in parallel supporting the creation of a competitive, circular, and sustainable European battery manufacturing value chain (more detailed information below).

[40] *'Open strategic autonomy' refers to the term 'strategic autonomy while preserving an open economy', as reflected in the conclusions of the European Council 1 – 2 October 2020.*

b. Increased efficiency of Europe's **cities' and communities'** energy, resource use and mobility patterns and cities' and communities' overall sustainability, thereby improving their climate-resilience and attractiveness to businesses and citizens in a holistic fashion. This also includes improved air and water quality, resilience of energy supply, intelligent mobility services and logistics, liveability and accessibility of cities, public health, comfortable, affordable zero emissions housing as well as the exploitation of relevant European technologies and knowledge (more detailed information below).

c. Facilitating the transformation to a climate neutral society, in line with the EU's 2050 climate targets, through more effectively **engaging and empowering citizens** to participate in the transition, from planning to decision-making and implementation (more detailed information below).

d. Nurturing the development of **emerging technologies** with high potential to enable zero-greenhouse gas and negative emissions in energy and transport (more detailed information below).

<u>A competitive and sustainable European battery value chain</u>

Batteries will enable the rollout of zero-emission mobility and renewable energy storage, contributing to the European Green Deal and supporting the UN SDGs by creating a vibrant, responsible and sustainable market. Besides climate neutrality, batteries also contribute to other UN SDGs directly and indirectly such as enabling of decentralized and off-grid energy solutions.

The strategic pathway is, on the one hand, for Europe to rapidly regain technological competitiveness in order to capture a significant market share of the new and fast growing rechargeable battery market, and, on the other hand, to invest in longer term research on future battery technologies to establish Europe's long term technological leadership and industrial competitiveness

The Partnership "Towards a competitive European industrial battery value chain for stationary applications and e-mobility", with as short name Batt4EU, to which all battery-related topics under this Destination will contribute, aims to establish world-leading sustainable and circular European battery value chain to drive transformation towards a carbon-neutral society.

The main impacts to be generated by topics targeting the battery value chain under this Destination are:

1. Increased global competitiveness of the European battery ecosystem through generated knowledge and leading-edge technologies in battery materials, cell design, manufacturing and recycling.

2. Significant contribution to the policy needs of the European Green Deal through new solutions for circularity and recycling of batteries.

3. Accelerated growth of innovative, competitive and sustainable battery manufacturing industry in Europe.
4. Development of sustainable and safe technologies and systems for decarbonisation of transport and stationary applications.
5. Contributing to the strategic independence of Europe through investigation of alternative battery chemistries using non-critical raw materials and efficient recycling technologies.
6. Increasing synergies with other partnerships and initiatives.

Emerging breakthrough technologies and climate solutions

Although the contribution of a wide range of technologies to reach climate neutrality is already foreseeable, EU R&I programming should also leave room for emerging and breakthrough technologies with a high potential to achieve climate neutrality. These technologies can play a significant role in reaching the EU's goal to become climate neutral by 2050.

Relevant topics supported under this Destination do not duplicate activities supported under Pillars I or III, but focus on emerging technologies that can enable the climate transition and follows at the same time a technology-neutral bottom up approach and the support of key technologies that are expected to support achieving climate neutrality. Research in this area is mostly technological in nature but should also where relevant be accompanied by assessments of environmental impact, social and economic impacts, and possible regulatory needs as well as activities to support the creation of value chains and to build up new ecosystems of stakeholders working on breakthrough technologies.

The main expected impacts to be generated by the topic targeting breakthrough technologies and climate solutions under this Destination are:

- Emergence of unanticipated technologies enabling emerging zero-greenhouse gas and negative emissions in energy and transport;
- Development of high-risk/high return technologies to enable a transition to a net greenhouse gas neutral European economy;

A competitive and sustainable European battery value chain

D2-1-1. Technologies for sustainable, cost-efficient and low carbon footprint downstream processing & production of battery-grade materials

Opening	2023
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Research and Innovation Action
Technology readiness level	Activities are expected to achieve TRL5 by the end of the project

Expected outcomes:

Projects are expected to contribute to all of the following outcomes:

- Increased European competitiveness by offering sustainable, safe, energy efficient and low carbon footprint battery materials production technologies and scalable solutions and create new business opportunities and models for EU industry.
- Battery-grade intermediates which are developed, produced and refined/purified in a sustainable and socially acceptable way, improving the competitiveness and value of European battery and mobility industries.
- Proven technical feasibility of downstream processing for battery-grade materials at larger scale, considering economic feasibility, safety, health and regulatory targets.
- A stronger EU battery manufacturing industry, through the implementation of continuous processes related conditions at larger scale with reduced carbon emissions, increased energy efficiency and more efficient resources use; (e.g. combining secondary materials into existing primary processing).
- Use of European low-grade deposits and secondary material sources such as tailings (e.g., as a source of nickel, cobalt and lithium) or underutilised battery raw materials deposits and extend the local refining capacity of battery-grade materials, to reduce the dependency on imported materials and to limit supply risks.

Scope:

The proposals are expected to cover research and innovation activities with focus on improved battery metal and material production, refining and recovery while minimizing environmental impact of downstream processing by addressing all of the following points:

- Developing sustainable and cost-efficient processing methods for battery-grade materials and components, coming from either primary or secondary streams; enabling thereby vertical integration into the battery production.
- Increasing the sustainability of batteries materials by reducing the use of chemicals and energy use in the downstream processing considering the objectives of the battery regulations and the LCA or similar approaches.
- Developing novel technologies for battery metals processing enabling the reduction of CO_2-footprint and VOC emissions and increasing energy and resource efficiency.
- Developing and demonstrating technologies to improve battery grade metals and materials production, refining and/or recycling with efficient and stable reagent circulation targeting low use chemical and environmentally friendly processes, while improving recovery rate/grade and yield considering the SRIA objectives and KPIs, the Green Deal objectives and the EU Battery regulation.
- Pre-assessing recycling concepts by their economic, ecological, and safety impact (LCA).
- Addressing zero waste and zero discharge strategies for the valorisation of the generated waste materials during the refining processes and improve the reuse of waste where CRM are present.
- Addressing understanding of physico-chemical mechanisms for hydrometallurgical steps in order to propose significant processes' improvements to reduce significantly water effluents quantities and chemical reagents.
- Implementing of continuous process for cathode active materials (pCAM) related conditions at larger scale.

Proposals are expected to enable the assessment of overall techno-economical solutions for recovery systems in order to minimize cost, environmental impact and system losses.

D2-1-2. New processes for upcoming recycling feeds

Opening	2023
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.

Type of action	Research and Innovation Action
Technology readiness level	Activities are expected to achieve TRL 4 by the end of the project

Expected outcomes:

Projects are expected to contribute to all of the following outcomes:

- The development of recycling technologies targeting upcoming recycling feeds and producing high quality precursors, semi-products and battery materials enabling their use in the battery production and other production processes.
- Achievement of the recycling targets as described in the battery regulation by industries, especially for low metal and low material value components.
- Recycling chains with reduced overall CAPEX & OPEX ready to be rolled out for the battery recycling industry.
- Safeguarding of the sustainability, low CO2 footprint, low chemicals usage and minimal emissions of newly developed recycling processes.

Scope:

Focus will be in improved and verified circularity of collected, dismantled and pre-treated battery waste feeds (Strong interaction with call "Advanced sustainable and safe pre-processing technologies for End-of-Life batteries recycling (2024)" is encouraged). All recycling concepts should address waste stream(s) in question in a comprehensive manner, aiming at the maximal recovery of input elements and components, rather than selected fractions. Focus in all concepts should be kept on recycling process development; a maximised material recovery efficiency, operational energy efficiency, mass- and energy balance, purity of the products and verified holistically decreased CO2 footprint. Battery development is out of the scope, interaction with other projects is, however, encouraged. At least some of the following topics should be addressed:

- New recycling concepts targeting the recycling of economically low value materials, e.g. from Lithium-iron phosphate or sodium-ion technologies. To enable recycling of low value battery compositions, new recycling concepts should be developed, including direct recycling routes that may include selective material recovery technologies and the reconditioning of the active materials. The additional recovery and recycling of non-cathode component materials are encouraged.
- Highly efficient recycling of battery production scrap that should include direct recycling concepts to re-introduce the materials in the battery production chain, including the handling and processing of relevant semi-material.

- Highly robust or flexible processes for the recycling of material streams of varying composition and quality may be covered.
- Material feeds from other industries (e.g. Ni/Co rich materials) may be introduced into the recycling concepts.
- Material feeds from future battery technologies with an expected market introduction no later than 2025 may be included.
- The processing of side streams (e.g. waste waters) may be targeted.

All proposed recycling concepts must be pre-assessed for their economical, ecological and safety impact.

D2-1-3. Advanced materials and cells development enabling large scale production of Gen4 solid-state batteries for mobility applications

Opening	2023
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology readiness level	Activities are expected to achieve TRL 6 by the end of the project

Expected outcomes: Building on the results of earlier research projects on solid-state advanced materials, the objective of this project is to demonstrate, at cell level, the scale-up of solid-state advanced materials for anodes, cathodes, electrolytes and separator with performances and costs compatible for the automotive market.

Projects are expected to contribute to all the following outcomes:

- Finalise the selection of solid-state cell components and architecture (anode; electrolyte, cathode, collector, and interfaces) meeting the performances at ambient t° requested by the automotive market in terms of:
    - Safety: with a technology compatible with the level 4 EUCAR at module/pack level.

- Gravimetric and volumetric energy density: > 400Wh/kg and 1000Wh/l.
  - Cycling: > 3000 cycles at 50% DoD (depth of discharge).
  - C Rate: up to 3 to 5 C at 80% SoC (state of charge).
  - Competitive cost: 75€/kWh.
  - Materials and cells design with mechanical properties and constraints that enable large scale production processes at a competitive cost, especially in terms of pressure conditions at cell and module level.
  - Atmospheric conditions in factories (dry atmosphere, etc…).
- An optimised environmental footprint of cell materials in terms of carbon footprint and quantity of metals.
- Cell manufacturing processes which allow the fabrication of performant, reliable, sustainable, and affordable solid-state cells, demonstrated at pilot level.
- Cell materials and designs which are compatible with a recycling process that respects the requirements as put forward in the European Batteries regulation.

Scope:

Proposals must cover all the following points:

- Develop or leverage material-specific models and digital tools for material and cell design to identify the best combination of materials and speed up the cell optimization process.
- Ensure ionic conductivity and stability of the electrolyte.
- Integrate high voltage cathode (> 4V) to reach the KPIs requested by the automotive market as listed in the Expected Outcomes section.
- Propose and evaluate interfaces and coating solutions especially to suppress Lithium dendrite growth and enable a stable solid-electrolyte interphase (SEI) and cathode-electrolyte interphase (CEI).
- Adjust the respective thicknesses of all the cell components to meet high energy density objectives.
- Anode current collectors and/or electrolyte capable of accommodating volume changes upon charge/discharge.
- Demonstrate the potential for scale up of materials, cells and sustainable industrial processing methods with cells reaching a capacity of several Ah, produced in a statistical meaningful number to demonstrate the process repeatability.

Projects should be aligned with ongoing Horizon Europe calls, especially **HORIZON-CL5-2021-D2-01-03: Advanced high-performance Generation 4a, 4b (solid-state) Li-ion batteries supporting electro mobility and other applications.** They should also take stock of the outcomes of the projects under call LC-BAT-1-2019 (Strongly improved, highly performant ad safe all-solid-state batteries for electric vehicles).

D2-1-4. Sustainable high-throughput production processes for stable lithium metal anodes for next generation batteries

Opening	2023
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action (IA)
Technology readiness level	Activities are expected to achieve TRL 6-7 by the end of the project

Expected outcomes:

As Li metal anodes will be needed for the Gen 4b, Gen 4c and Gen 5 batteries, it is important to create a European production chain for their manufacturing, in order to guarantee secure supply chains for the next generation battery producers with a focus on high performance and recyclability for Gen 4b, Gen4c or Gen5 cells.

The proposed project must contribute to the following outcomes:

- Price competitive contributing towards 75€/kWh at pack level.
- Energy consumption/carbon footprint of production lower than [TBC on basis of ongoing projects].
- Throughput of Li foil and/or electrode production to support cell manufacturing, including a technical pathway towards production at MWh/(sub-)GWh scale.
- Ensure stability of Li during handling, processing and operation using coatings or other protective technologies (e.g. barriers/protective layers).

- Processing of Li (Metal) and Li electrodes within cell assembly at industrial scale, including, but not limited to, high-quality cutting of the Li foil and/or electrode.
- Homogeneous Li films with thickness below 20µm, contributing towards energy density levels of 400-500 Wh/kg.
- The developed process should be compatible with recycling targets (with respect to purification of scrap with protective coating) and assure recyclability to more than 70% of Li metal in spent batteries, (90% Li metal for production scrap).
- Collaboration with other projects from calls [TBC – calls on Gen 4 and or Gen 5] is expected

Scope:

Proposals under this topic should focus on sustainable, cost-efficient and large-scale production of Li-metal foils and/ or electrodes, demonstrated up to pilot level during the project. Activities can include, but are not limited to, extrusion, comparison extrusion / electrostatic spray, rolling and co-rolling.

The projects should also aim to control the passivation of Li metal films, and to understand how the passivation is linked with the dry room conditions and requirements. The goal is to find the optimal way: high passivation and lower quality dry room, or low passivation and higher quality dry room, and how these selections are linked with cost, energy consumption and performance of the cells.

The projects should demonstrate the performance of Li at cell level in SoA benchmark cell (at least TRL5 with at least 5 Ah capacity). However, extensive cell design and development are out of the scope as this topic focuses on the Li anode production. It is expected that the Li metal anode (with protective layers) allows more than 1000 cycles (C/2 or C? TBC) with min. 400 Wh/kg. The projects should also guarantee safety of the Li film production and handling.

D2-1-5. Advanced digital twins for battery cell production lines

Opening	2023
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.

Type of action	Research and Innovation Action (RIA)
Technology readiness level	Activities are expected to achieve TRL 4-5 by the end of the project

Expected outcomes:

The European battery cell manufacturing industry is on its rise. However, there are several challenges associated with the development of competitive, high quality, battery cell manufacturing capacities in the upcoming Gigafactories, like the increase of the production efficiency and the reduction of battery scrap, which should be addressed at pilot plant scale, prior to their implementation in large-scale manufacturing facilities. In this sense, it is indispensable to optimise and improve the overall manufacturing process. Digitalisation tools, such as digital twins, bring the opportunity to optimise product quality, improving the resource efficiency and, consequently, the production time and cost of battery cells in the manufacturing process at the targeted scale.

Projects are expected to contribute to all of the following outcomes:

- The understanding of digital twins as systems with automated data acquisition, connected digital models and value-adding applications
- The capacity to go beyond single process consideration with potential perspective on the process chain
- The implementation and the transfer of digital twins into existing and future battery cell production plants
- Important aspects like safety and security, scalability, explainability, computational speed as well as contributions to sustainability of battery cell production

Scope:

The battery production chain consists of diverse multi-disciplinary, rather novel processes with numerous influencing factors and interdependencies. Digital twins, as a core element of the accelerating digitization in manufacturing, bear the potential to improve planning and operation of current and future battery production system. With their connection of advanced digital models and most up-to-date data, decision support or even autonomous control of battery production processes and process chains is enabled. First applications can be found in research and partly also in industrial practice – however, those still tend to be rather specific, cover just selected aspects of digital twins (e.g. just specific model) and are often hardly transferable in terms of the underlying IT architectures and models.

.Proposals must address all following points:

- Developing digital twins of battery cell manufacturing routes at pilot line level that incorporate appropriate models but also their connection to real manufacturing plants, e.g. to support process development and operation, accelerate the set-up of effective manufacturing processes for the next generation battery cells or to demonstrate the capability for predictive maintenance.
- Design robust digital tools integrating multi-physics and data-driven models.
- Flexible Digital Twins capable to evolve to different battery chemistries, new disruptive materials as well as new manufacturing processes (the model would be chemistry neutral so easily adaptable to new disruptive materials and chemistries)
- Verify the transferability from pilot to production plant level
- Propose applications that will enable to overcome single process considerations towards process chain perspectives
- Implementation of the sensorisation of the manufacturing plant and automation of the data acquisition.
- Ensuring greater interoperability, by implementing available data standards, e. g., Modelling-Data (MODA) and Characterization Data (CHADA), as well as, a common semantic framework, like The European Materials Modelling Ontology (EMMO) and the battery interface ontology (BattINFO).
- Promote the control and decision making of the manufacturing chain.
- Aspects like safety and security, explainability of models as well as contributions to sustainability of battery production must be addressed

Building upon the shared data infrastructure, standards and protocols developed in the BATTERY 2030+ initiative, and in particular to the BIG-MAP project, this call topic addresses the need of increasing the level of autonomy to the whole battery cell value chain (with special emphasis in the manufacturing). The proposal should also cover the contribution and collaboration to the BATTERY 2030+ large scale initiative.

D2-1-6. BMS and battery system design for stationary energy storage systems (ESS) to improve interoperability and facilitate the integration of 2nd life batteries

Opening	2023
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology readiness level	Activities are expected to achieve TRL 6 by the end of the project

Expected outcomes:

This topic builds on the results of HORIZON-CL5-2022-D2-01-09: Physics and data-based battery management for optimised battery utilisation (Batteries Partnership) and will specifically address BMS and system design issues that affect stationary Energy Storage Systems (ESS) and in particular the integration of used batteries as a 2^{nd} life application.

Projects are expected to contribute to all of the following outcomes:

- Battery pack and Battery Management System (BMS) design for single module operation or recombination (reconfiguration) of modules or battery packs.
- Safe, accessible and reliable operation of batteries and enabling of the battery passport concept.
- Battery system design to enable disassembly and reconfiguration for 2nd life:
- Development of fast and efficient qualification strategies and assessment of Electric Vehicle (EV) batteries for 2nd life applications and quantify it with respect to SoA in terms of time and efficiency.
- Reduction of 10% of repurposing/refurbishment cost for adapting EV batteries to stationary applications in 2nd life.
- Impact in the European economy by a growth of the market and employment, by facilitating the uptake of stationary ESS Feasibility of operation in the batteries extended life domain (2nd life)

Scope:

This topic aims at developing an open and interoperable BMS and suitable battery system design for stationary ESS, enabling a better integration of 2nd life applications for used batteries. In order to fulfil these objectives, activity in all of the following fields is expected:

- The BMS should be used for 1^{st} and 2^{nd} life batteries in stationary applications, e.g., microgrids, uninterrupted power supply, hybrid (different types of chemistries and batteries, multibattery management systems) and circular power system, ensuring safety during operation.

- The BMS and system design should be technology agnostic and not exclusive to 2nd life EV batteries and can cover consolidated technologies as well as new battery technologies.

- Development and validation of open-source algorithms and BMS, allowing for the integration of 2nd life batteries including data-driven supported battery state estimators. Recommendations for the development of standards related to the battery state defining parameters, e.g., SoH and safety assessment at the end of first life applications.

- Development of BMS software that can be adapted via firmware update to other communication protocols, estimation algorithms and models.

- Development of functionalities focused on increasing the reliability during the second life application, e.g., prediction of RUL, self-diagnostic algorithm for assessment of second life use suitability and BMS connectivity to track batteries during 2nd life application.

- Recommendation to standardization of a BMS public structure and access to public SOX in order to ease the second use of a battery. The goal must be to agree a minimum set of data requirements, duly justified, to be provided by the batteries and let the industry define the best procedure to provide this set of data and link up with battery passport concept.

- Definition of a common interface (multi-brand) capable of linking to the batteries coming from EVs to facilitate their use in 2nd life applications. This common interface will link to the batteries once they are no longer part of the vehicles and include the HW and SW as much as possible.

- Development and demonstration of strategies to recombine optimally and safely used batteries to be operated in second life, with special focus on advanced critical event control and mitigation systems. Recommendations for standardization of 2nd life battery system design for stationary applications based on packs, type of chemistry and cell.

- Design of accessible and adaptable BMS in order to customize the BMS to the requirements of the 2nd life use case.

- Demonstration of battery operation in second life use according to TRL6.

- Projects are expected to share information with projects emanating from [Battery Passport topic] where relevant and conform to all relevant EU standardisation requirements.

- The proposal should take into account pending amendments to the Renewable Energy Directive, including Article 20A dealing with access to battery SOX information.

D2-1-7. Hybrid electric energy storage solutions for grid support and charging infrastructure

Opening	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology readiness level	Activities are expected to achieve TRL 7 by the end of the project

Expected outcomes:

Electrical energy storage systems are a solution to address the challenges posed by the increased penetration of renewable energy source that is needed for decarbonising the European energy system. Hybrid energy storage (HESS) systems consisting of multiple, heterogeneous EES elements enable exploiting the advantages of the EES elements while hiding their shortcomings with aid of system-level management. HESS can provide multiple services (e.g. artificial inertia, frequency regulation, renewables balancing, load levelling, backup power and longer-term energy storage) thus reaching better business cases. However, such benefits can be achieved only by elaborate optimisations during design and operation.

Projects are expected to contribute to all the following outcomes:

- Demonstration of hybrid energy storage technologies for long duration storage (from days to weeks) and provision of multiple grid services with improved technical and sustainability performances as well as increased safety during operation, transport and storage
- Enable improved levelized cost of storage supported by design optimisation and optimal service stacking, putting the cost of storage on the path to fall below 0.05 €/kWh/cycle by 2030 (at least for storage durations up to X days – TBC) while reducing the use of CRMs
- Creating synergies between producers and strengthening the European Battery Ecosystem, improving the European battery value chain and thus contributing to the EU climate neutrality objectives.

- Increasing digitalisation of energy storage systems from design to operation phase enabling a faster development and optimal use in grid applications
- The establishment of multi-service approaches to energy storage reducing costs and increasing benefits for the European electricity system
- Promoting an increased reliability and resilience of the electricity system by demonstrating new multi-purpose energy storage solutions

Scope:

The objective is to design and demonstrate in at least three different use cases a Hybrid Energy Storage System (HESS) capable of long duration storage and provision of multiple services for supporting the electrical grid and EV charging infrastructure. In particular proposals should:

- Design and demonstrate a sustainable and safe Hybrid Energy Storage System (HESS) either combining different battery technologies or combining batteries and other electrochemical storage technologies aiming at providing long duration storage while ensuring the possibility of service-stacking and enabling ultra-fast services. The proposed storage solution should be scalable and modular. Proper power conversion devices should be selected or customized for enabling an efficient operation of the hybrid storage in grid-connected, grid-following and grid-forming modes;
- Perform a life cycle assessment of the HESS starting from the design phases to ensure its sustainability along the entire value chain, also avoiding, whenever possible, or limiting the use of CRMs;
- Develop physics-based and data-driven digital models of HESS supporting optimal design, and real-time management and diagnosis as well as facilitating the inclusion of storage in grid-planning processes considering forecasted weather conditions, production and consumption. Models should allow the combination of different battery technologies based on specific use cases;
- Develop and validate management policies and control systems (BMS, EMS) for HESS that maximise the benefits of a hybrid storage, facilitate asset management and participation in electricity and service markets;
- Demonstrate HESS integration in standard grid architectures (Smart Grids Architecture Model – SGAM) ensuring interoperability for most use cases of ESS (e.g., provision of services to the European grid, supporting islanded and weak distribution grids, load levelling for charging stations);
- Analyse of business cases of the proposed hybrid solution considering electricity and balancing markets of three representative EU countries, also assessing the applications where HESS provides improved techno-economic performances compared to non-hybridized storage systems.

The proposals may also address multi-location hybrid energy storage systems.

D2-1-8. New Approaches to Develop Enhanced Safety Materials for Gen 3 Li-Ion Batteries for Mobility Applications

Opening	2023
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Research and Innovation Action
Technology readiness level	Activities are expected to achieve TRL **5** by the end of the project

Expected outcomes:

Advanced Li-ion batteries with enhanced safety behaviour, delivering competitive performance against currently defined market KPIs in terms of cost, energy and power density, cyclability and operational lifetime, sustainability and recyclability (SRIA and HE battery related calls), with clear prospects for industrial up-scale manufacturing.

The enhanced safety behaviour may be achieved by combining some, or all, of the following cell components:

- New cathode materials with no exothermal decomposition/reactions, reduced probability for oxygen and other gasses release, and preventing corrosion at current collector.
- New stable anode materials and electrode designs with non-swelling, or low degree of expansion over the whole cell lifetime, with no decomposition/exfoliation, high resistance against Li-dendrite formation – specially at high anode rate capabilities, and favouring the formation of a thermally stable, and low-resistivity SEI.
- New electrolyte formulations, including solvents, supporting salts and additives, with shear thickening, flame retardant and over-charge/discharge properties, maintained high ionic conductivity, broad electrochemical stability i.e., voltage-operating window, and high onset point for Li-dendrite formation, SEI decomposition and CEI effectiveness.

- New separator materials with flame retardant and improved ion transport capabilities, high melting point, and mechanical stability.

- New binder materials with thermal, mechanical and electrochemical stability (self-healing systems), low ionic and electrical resistance, improved adhesion and cohesion, and preventing swelling and porosity reduction in electrodes.

Projects need to justify the relevance of the selected components which will be addressed and how the new materials, and the combination of them, will lead to better safety outcomes.

The improvement in safety should be demonstrated at representative cell level for mobility applications by direct comparison with SOA Gen. 3 cells tested at the beginning of the project. A EUCAR Hazard Level of 3 or other equivalent mobility standard should be validated.

Scope:

This call aims at developing safer materials for high-performing cells by targeted modification in main cell components, namely the cathode, anode, separator and electrolyte. The most severe danger arises from exothermic reactions inside the Li-ion batteries, interaction of the individual materials used in the cell with organic and/or contaminants, and other risks related to the high intrinsic electrical and thermal energy density of active materials (anodes and cathodes in the charged state of the cell), and/or unwanted side reactions under peculiar operating conditions (Li-dendrite formation, temperature induced oxygen loss of cathode materials, uncontrolled interactions on SEI and CEI, etc.).

Effective countermeasures should be undertaken by material modification on electrolyte, electrode and separator manufacturing level to mitigate and minimise aforementioned risks, reduce the probability of thermal-runaway effects, and enhance the intrinsic safety of the cell. The multiple aspects of safety enhancement must be covered through a comprehensive design of new materials that may include some of the following approaches/strategies at different levels:

- Cathode:
    - Doping strategies (e.g. ALD, PLD, chemical…) or surface coating materials leading to more robust and effective cathode electrolyte interphase (CEI).
    - Design of high-capacity cathode materials based on safer chemistries (e.g. stabilized Li-rich layered oxides, disordered rock salts, polyanionic materials…).
    - Design high-voltage cathodes and high voltage anodes in order to combine them in a large voltage and energy cell, avoiding stripping/plating of lithium.
    - Innovative approaches of cathode structuring to mitigate heat generation in abuse conditions.

- Anode:
    - o Design and development of new systems with higher standard potential compared to lithium stripping/plating. (High SiOx, Si/C, etc. content)
    - o Surface coating materials for more robust and effective SEI.
    - o New approaches to minimize material/anode swelling and expansion during cycling, including anode manufacturing (polymeric and ceramic coating-based approaches, etc.) and structuring the anode-current collector interface.
- Electrolyte:
    - o (Multi-)functional additives for SEI and CEI stabilization and protection on anode and cathode such as flame-retardant additives or solvents, ionic conductivity boosters, stability window promoters, etc.
    - o Addition of selective particles (i.e. oxides, etc.) to hinder mechanical abuse and improve shear thickening behaviour.
- Separator:
    - o Multilayer approaches for disruption of ionic conductivity (shutdown effect) and maximize electrode voltage compatibility.

D2-1-9. Creating a digital passport to track battery materials, optimize battery performance and life, validate recycling, and promote a new business model based on data sharing

Opening	2023
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology readiness level	Activities are expected to achieve TRL 7 by the end of the project

Expected outcomes:

Stakeholders engaged with the battery value chain, need to be provided with accurate, reliable and immutable battery information e.g. related to ESGE (Environmental, Social, Governance & Economic) indicators at any stage of the value chain. The increase in sales of EVs and other ESSs in Europe increases the need to promote new business opportunities around the whole battery value chain, which will improve battery life span and second life application opportunities. Furthermore, the Battery Regulation and future regulations will extend the due diligence to all domains in the next few years. The EU Data Strategy is setting a clear architectural approach to federated data and is enabling a great opportunity to boost the EU dataspace on batteries.

The availability of shared, interoperable, and trusted data might promote new business opportunities for improving recycling and second life application, assuring workforce and transportation safety. Indicators such as SoH (State of Health), SoS (State of Safety), SoP (State of Power) should be calculated in accurate, reliable, immutable, and standardized way, based on historical data (usage profile, working temperatures, …) of the battery or cells.

Projects are expected to contribute to all of the following outcomes:

- A proper tracking and blockchain or DLT (Distributed Ledger Technology) based solution, along the value chain, with no data duplication, avoiding data manipulation and promoting data interoperability.
- New business models in the different value chains and circular data extraction, based on data sharing
- Improvement of the battery transportation and workforce safety
- Testing throughout the battery value chain, real life pilots capable to exploit data generated by Digital Product Passport (DPP) and test innovative solutions proposed.

Projects are also encouraged to address some of the following outcomes:

- Improvement of the recycling efficiency (more than one material)
- Promotion of sustainability and circularity through the adoption of 4R methodological approach Reduce, Repair, Reuse, Recycle
- Boost of the use of recycled and reusable material to reduce energy usage/CO2 footprint
- Increase of competitiveness of the European battery industry across the value chain (from mines and refiners to cell manufacturers to cell integrators);
- Streamlined compliance with the European Battery Regulation and EU federated dataspace.

Projects need to be compliant with the following EU strategy and regulations framework:

- Green Deal and in particular Circular Economy Action Plan's Sustainable Product Initiative,
- the EU Digital strategy's Circular Electronics Initiative and
- the EU Data strategy,
- New Regulation on Batteries / Due diligence

Scope:

The project should promote the adoption of a downstream development and implementation of a battery pack Digital Product Passport (DPP) at minimum subset design system level addressing raw materials (at least anode and cathode critical raw materials), cells and modules. The project should also be able to assure real-time data gathering for different indicators and refining optimisation at local device - even when the battery ceases to be part of the ESS.

The project should engage a variety of stakeholders along the battery value chain to assure the continuous traceability and assure that accountability will not be lost. Blockchain solutions are requested to demonstrate trustworthy tracking. The funded projects under this call will be requested to work in a cluster approach, to validate its interoperable data sharing strategy by adopting a unique battery data space and testing of interoperability between different systems is encouraged.

In particular, aiming a safety second life-battery certification protocol, and hazard alerts system need to be developed to assure liability and protection during transport, and second use. The projects will validate new business models, capable to demonstrate improvement in remanufacturing, repurposing and recycling. International collaborations are welcome and alignment and interoperability with the Global Battery Alliance and other worldwide networks is encouraged.

Projects should have an ambition for cross-sectorial applications and should focus on the lithium-ion battery chemistries currently on the market - or reaching the market in the short term, with the potential to quickly adapt to next-generation battery chemistries.

Project outcomes should be applicable to one or several use cases among the main transport or mobile applications (such as road, waterborne, airborne and rail transport, as well as non-road mobile machinery and industrial applications), with the aim to maximize the impact on the European industry.

Projects may consider the key performance indicators proposed by Batteries Europe or by the dedicated Partnerships, reflected in the Partnership Strategic Research Agenda (SRA), to guide the technology developments on the application segments and use cases that will be selected.

The project results shall also be applied to stationary energy storage applications.

Proposals should interface with the project(s) funded under the topic DIGITAL-2021-TRUST-01-DIGIPASS and notably its activities regarding batteries. They should also establish cooperation and complementarity with the selected proposal under the topic HORIZON-CL4-RESILIENCE-01-05 which is tracking raw material flows for a.o. batteries value chains. They should furthermore establish collaboration with the partnership "Battery Passport" under the Global Battery Alliance. [41]

D2-1-10. Advanced sustainable and safe pre-processing technologies for End-of-Life (EoL) battery recycling

Opening	2024
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Research and Innovation Action
Technology readiness level	Activities are expected to achieve TRL 5 by the end of the project

Expected outcomes:

The pretreatment process is the first and indispensable step in recycling Lithium-ion batteries (LIBs), which significantly affects the recycling rate of the spent devices and the extraction rate of the high-value metals in the subsequent metallurgical processes. The batteries also contain toxic chemicals, which should be preventatively separated to promote environmental protection and sustainability. Moreover, the pretreatment processes also help to reduce the scraps volume and allow the separation of the battery components.

Projects are expected to contribute to all of the following outcomes:

- The direction of the EU battery industry towards the zero-waste concept by developing holistic materials and energy efficient recycling processes that can increase the content of recovered mass and by improving the cooperation between recyclers and battery manufacturing through a vertical integration strategy.

[41] https://www.globalbattery.org/battery-passport/

- The circularity of battery materials, where also non-metallic elements (electrolyte, solvent, salts and polymers) are recycled back to use (as raw materials or valuable chemicals). The "cradle to cradle approach" will be addressed though waste pre-treatment by safe and sustainable separation and recovery.
- Environmentally beneficial processes for battery pre-treatment (pre-processing and separation) of the main elements to decrease the CO_2 footprint and other emissions of the recycled materials.
- Safe technologies aimed at improved recovery yield (including minor elements), increased quality and purity level of the recycled/recovered materials, improved impurity removal.

Scope:

The current EOL LIB recycling technologies are focused on improving the recovering efficiency of Cobalt that is the most valuable material. However, other no-Co battery contents need to be extracted in one go to develop recycling processes with economic, societal and environmental perspectives. They, for instance, include low-density plastics, metal shells and foils, binders, separators, organic solvents, Li salt, anode active materials. Successful separation methods have the potential to enrich the constituent of targeted materials and improve the profit for recycling.

In recent years, several pretreatment processes were tested at least at lab-scale (usually mechanical, thermal and chemical options). The goal is to develop and integrate new advanced pre-processing concepts that enable more efficient and safe technologies for recycling EoL LIBs. Substantial improvements should be achieved in the processes environmental and economic viability and in the circular economy, narrowing the sustainability gaps in the whole battery recyclates pre-treatment.

Some of the following pre-treatment concepts should be addressed:

- Battery sorting at component level that should be more efficient, accurate, including standardisation of labelling, due to the huge variation of physical configurations, cell types and chemistries;
- Advanced pre-processing methods including (but not limited to) physical, mechanical, dry, thermal and aqueous pre-treatment methods that allow improved pre-concentration while minimising as much as possible waste side products;
- Recycling process design enabling the recovery and valorisation of anode materials (graphite, silicon);
- Electrolyte valorisation through the development of sustainable and safe processes for the recovery of Li-salts;
- Separation of all the strategic battery materials that should be integrated into existing/innovative recycling processes to mitigate potential effect of impurities.

- Recovery of electrode current collectors (Al and Cu) that should be improved by developing more efficient separation methods of the metal foils from the electrode materials and easier removal of the organic binder;
- Other recoverable not-active materials from the EoL battery (solvent as EC, DEC, DMC, binders, separator).

All the proposed pre-processing technologies must be assessed by their economical, ecological and safety impact (LCA).

The topic will generate insights that may be of use for on-going Research and Innovation on new recycling processes and concepts [call number TBC].

Proposals are encouraged to establish synergies with other Partnerships such as Processes4Planet.

D2-1-11. Scale-up of automation for safe and flexible battery disassembly

Opening	2024
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology readiness level	Activities are expected to achieve TRL 7 by the end of the project

Expected outcomes:

While today the volume of post-use batteries is still limited, the predicted market growth, both in automotive and stationary applications, calls for the development of innovative, highly flexible and safe automated solutions for battery packs/modules/cell disassembly.

In recent years, lab scale processes for the automation of battery disassembly have been designed and preliminarily tested in different contexts. The goal is to integrate in a process-chain and scale-up the developed technologies in order to develop a safe and flexible disassembly/dismantling framework of battery packs/modules/cells. The focus is on industrial, both EV and stationary, batteries that may be addressed with synergic approaches.

The disassembly/dismantling process-chain shall target both the case of packs/modules/cells disassembly for remanufacturing/re-use in specific applications and for recycling.

Due to the variability of the treated battery systems (in terms of geometries, connections, chemistries, …), a hybrid automation solution is envisaged, in which the human operator safely cooperates with the robot. Strategies for the safe uptake of humans would in fact allow to increase the robustness and flexibility of the disassembly/dismantling process-chain, with the aim of increasing the disassembly selectivity while isolating components for the maximization of their residual value. Methods and tools for the dynamic planning of disassembly tasks depending on the battery design and specific conditions and for selecting the most appropriate manual, automated or hybrid task execution modes should be developed, by jointly considering process performance and operator safety issues.

Projects are expected to contribute to all of the following outcomes:

- A demonstration of a decrease of human safety risks during battery disassembly processes thanks to a smooth integration of smart automation.
- A demonstration of the adaptability of the automation solution to a large variety of battery designs and conditions.
- A demonstration of volume upscale potential of the developed disassembly solutions in compliance with the predicted growth figures of the battery market in Europe
- The promotion of development of knowledge-intensive jobs in Europe through a smooth integration between human and automated solutions.
- Exploitation of digitalisation for improved process adaptation, safety, traceability.
- The development of economically viable circular business models for batteries based on integration of recycling, remanufacturing and re-use strategies depending on the battery conditions.

Scope:

The envisaged disassembly/dismantle process chain should optimally combine battery discharge and deactivation, mechanical disassembly operations on packs/modules/cells with in line diagnostic and testing steps, by using both traditional and innovative sensors that could allow a deeper understanding of the battery state, to guarantee the safety of the process and of the operators as well as to drive the downstream recycling/remanufacturing/re-use operations. In any case, the process should be carried out in a highly controlled environment in order to identify the onset of problems well in advance.

Digital tools for the tracking and monitoring of the testing and processing operations should accompany the disassembly/dismantle process-chain, driving its operation and adaptation. The gathered information should feed a Decision Support System (DSS) that optimises and adapts the downstream processing steps depending on the disassembly outcomes to maximise the economic and environmental impact of the process as a whole. For this purpose, the use of machine learning approaches is encouraged.

Proposals should include pilot applications capable of demonstrating the safe and flexible battery disassembly automation for at least five different battery pack models. A subset of specific battery chemistries may be addressed in the proposal.

Proposals are expected to address operator training activities and modules to guarantee the smooth industrial uptake of the developed technical solutions after the end of the project.

Proposals are encouraged to establish synergies with other partnerships such as EURobotics and MadeInEurope.

D2-1-12. Post-Li-ion technologies and relevant manufacturing techniques for mobility applications (Generation 5)

Opening	2024
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Research and Innovation Action
Technology readiness level	Activities are expected to achieve TRL 4 by the end of the project

Lithium-ion (Li-ion) batteries are currently the most important technology driving the electric vehicles market growth. However, the request for higher gravimetric and volumetric energy densities, lower costs, higher sustainability, ubiquitous raw materials with high and improved safety has triggered research into Generation 5 battery concepts. These novel concepts include secondary batteries related to conversion systems based on metal anodes, e.g., lithium-sulfur (Li-S), magnesium-sulfur (Mg-S) etc. and Li–air, sodium-air (Na-air), etc. batteries as well as post lithium, but ion-based, technologies such as batteries based on potassium (K), magnesium (Mg), calcium (Ca), aluminium (Al), zinc (Zn) etc., which are drawing attention due to the higher abundance of these elements on Earth.

This call aims at developing Gen. 5 technologies and relevant manufacturing techniques for mobility applications.

Many issues are still to be taken into consideration and are also related to the manufacturability of batteries based on these new technologies, in term of performance, safety, costs and also their design to be fully and easily recyclable at the end of their life.

Current battery technologies based on the use of metallic anodes (mainly Li) are still suffering from various issues and need further development, particularly in solid-state configuration, e.g., high impedance at the electrode-electrolyte interface, low ionic conductivity at room temperature, short cycle life and no proper manufacturing technologies at a competitive cost. For this reason, sophisticated analysis methods are needed to investigate these new battery concepts in industrially relevant cell formats, such as pouch cells. The resulting mechanistic understanding of the degradation processes acquired in this way can be used to successively improve the battery materials in a feedback loop.

Batteries based on post-lithium-ion technologies commonly present issues related to finding low-cost anodes with high charge-storage capacity, good electrochemical oxidation stability with the electrolytes, insertion cathode materials with high specific capacity and high potentials, high practical gravimetrical and volumetric energy densities, high power densities, long cycle life, and high safety. In the context of manufacturability, the effects of different components such as but not limited to: active materials, electrolytes, separators, binders, current collectors etc. have to be carefully considered.

This call aims at developing the manufacturing processes for these technologies and evaluating their possible manufacturing compatibility with existing lithium-ion production infrastructure.

Expected outcomes:

Projects must contribute to at least one of the following outcomes:

- Conversion systems based on metallic anodes, e.g. Li-S, Li-air, Na-S, Mg-S, etc.. with enhanced safety, delivering on cost, performance, sustainability and recyclability, with clear prospects for the feasibility of the scale-up of the manufacturing processes.

- Metallic anode protection and/or activation for conversion systems (polymer, ceramic and hybrid electrolytes) with increased safety, cycle life and low cost.

- Post lithium-ion cells based on cations other than lithium (Na-ion excluded) with long cycle-life.

In addition, projects shall contribute to creating batteries that will work in realistic environments, are recyclable and with low environmental impact, and have safe manufacturing processes.

Translating these outcomes into indicative KPIs to guide the R&I efforts, projects must show a credible technical pathway to achieve the following targets by 2030 and beyond:

- A safe behaviour at cell level: expected EUCAR Hazard level below 4

- Specific energy at cell level targeting 500 Wh/kg, and volumetric energy density at cell level targeting 600 Wh/l
- Charge and discharge at 2<C-rate<10
- 800+ cycles at 80%DoD
- Cost at cell level < 75 euro/kWh

Scope:

Improvements in sustainable material designs to reach the manufacturability and high safety of the selected technology.

Successful projects are expected to cover all of (?) the following:

- Improvement of materials:
  - Scalable and manufacturable surface coating materials for metallic anode protection and/or activation (e.g. CVD, PLD, ALD…) to increase safety and cycle life
  - Binders with high chemical and thermal stability to reduce toxicity and enable the use of water-based manufacturing processes.
  - Design and development of new cell technologies with higher capacities compared to Li-ion cells.
  - Improve and increase the electrodes-electrolyte compatibility with additives to increase over cell time.
  - Improve the understanding of the chemical and/or electrochemical reaction mechanisms using advanced techniques in the cells for Gen5 technologies developed
  - Improve the insertion cathode with high charge-storage capacity
  - Use of safe and non-toxic materials.
  - New efficient and sustainable catalysts that can promote polysulfide conversion in Metal-S batteries or the oxygen evolution/reduction reactions in Metal-air batteries.
- Design and manufacturing:
  - Innovative cell design ensuring high performances, low cost and ready for recycling

- Develop relevant manufacturing processes and assess the possible manufacturing compatibility with the existing lithium-ion production infrastructure and production lines
- Proof of concept possibly at small pilot line scale
- Design production with low environmental impact, safe and healthy environment for workers, low energy consumption

Projects are encouraged to demonstrate also techno-economic suitability of the solution for other emerging markets, such as motive power for off-road applications, or energy storage applications.

D2-1-13. Non-Li Sustainable Batteries with European Supply Chains for Stationary Storage

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology readiness level	TRL 6-7 by project-end

Proposals are invited for projects that credibly advance the development of non-Li battery systems and prove the ability of relevant manufacturing processes to be scaled up and meet regulatory requirements, including regulations for the recycling/re-use of batteries.

Non-lithium-based batteries with sustainable supply chains will be required to provide the energy storage needed to fully exploit the potential of renewables and meet net zero carbon targets. Li-ion based battery (LiB) solutions initiated the ongoing revolution in electrification of transport, grid storage and other sectors. However, they are unlikely to be able to meet the markets requirements for all applications due to limited lithium and cobalt resources, the prices of which are forecast to increase steadily. Non-Li batteries have the potential to provide commercially viable and sustainable solutions for stationary storage applications and contribute to zero emission targets.

Local supply chains are important to reduce European reliance on critical raw materials and minimise the impact of tariffs from ‘rules of origin’ legalisation.

The scale of stationary storage is diverse, from a few kWh in small-scale domestic behind-the-meter units, to many MWh in large utility-scale front-of-meter installations. Whilst stationary storage packaging constraints may not be as stringent as mobile applications in terms of volume and mass, total cost (€/kWh/cycle) and safety are critical to proving technological and commercial viability. Safety concerns become especially prominent as installation sizes increase due to the huge amount of stored chemical energy.

Expected outcomes:

Projects are expected to contribute to all of the following outcomes:

- Development of post-lithium cell chemistries with target cell- and system-level cost, safety, energy density and power metrics suitable for the selected stationary energy storage markets;
- Reduction or replacement of critical raw materials;
- Credible projected storage costs of less than 0.05 €/kWh/cycle by 2030, at least for storage durations up to X days (TBC);
- Projected product cycling life of at least 5,000 cycles in conditions typical for the selected application;
- Demonstration of system operated in end-user conditions for at least 3,000 hours;
- A battery storage solution, whose complete system safety can be maintained across a wide range of ambient conditions;
- A clear route for a feasible, European-based supply chain;
- A defined concept for demonstrable, highly sustainable, circular manufacturing for the selected battery type, with sustainability measured in terms of recognised economic, environmental, social and ethical metrics.

Scope:

This topic is open to all non-lithium battery chemistries.

Projects must:

1. develop and demonstrate an innovative post-lithium battery technology with energy density and power metrics suited to stationary energy storage applications; and
2. prove the battery system’s sustainability and compatibility with a European supply chain.

In particular, projects must (?):

3. Develop and demonstrate sustainable and safe post-lithium battery solutions that can be deployed in a large share of the energy storage markets;

4. Develop new materials that improve techno-economic performances and/or the ability to meet sustainability targets;
5. Show how cell and system design and material improvements optimise techno-economic performance by defining (i) technical and commercial targets, and (ii) quantified success criteria/KPIs by which progress toward achieving the targets may be evaluated during both development and validation phases of the project;
6. Demonstrate a credible commercial and technical path, from end-of-project outcomes to a stationary-energy-storage product, and which takes account of future manufacturing and recycling requirements.
7. Provide evidence of current and future sustainability, viable European supply chains and rigorous analyses of the complex sustainability and recyclability issues including compatibility with regulation, including recycling regulations.

BMS development is within scope where relevant, but should not be the main focus of the project.

Projects which, in addition, demonstrate the suitability of the solution under development for other emerging energy storage markets, such as motive power for off-road and transport applications with similar system requirements are encouraged.

Projects focussed on materials discovery for novel chemistries are out of scope. However, material refinements of known chemistries undertaken to achieve performance, sustainability, safety and cost targets are in scope.

D2-1-14. Computer-aided design and development of materials for next-generation redox flow batteries

Opening	2024
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Research and Innovation Action
Technology readiness level	Activities are expected to achieve TRL 4 by the end of the project

Redox flow batteries (RFBs) are scalable and flexible energy storage devices that allow an independent sizing of power and energy, as well as high round-trip efficiency, high depth of discharge (DOD), long durability and fast responsiveness. For these reasons they stand as a highly attractive solution for long-duration grid-scale stationary energy storage systems.

Redox couples and electrolytes are the most important component in RFBs, as they largely determine system energy density and cost for grid-scale systems. However, other components such as electrodes and membrane/separator are also important since they strongly affect battery lifetime, energy density and cost. Large-scale deployment of RFBs requires the design and development of novel materials and new systems based on low-cost, sustainable, scalable and non-toxic materials. Organic and hybrid materials have a large potential which is currently not fully exploited.

RFBs are a complex system: their efficiency, durability and cost strongly depends also on a multitude of factors across different scale from materials to the system level. This adds significant complexity to the task of automated discovery of redox couples and electrolyte formulations. The timescale for deployment of novel materials from discovery to commercialization is typically over ten years. Combination of new computational methods, e.g., multi-scale and AI-assisted simulations, and adequate experimental techniques can effectively advance the predictive power of materials modelling and, therefore, reduce the commercialization timescale for materials for flow batteries.

Expected outcomes:

Building upon the shared data infrastructure, standards and protocols developed in the BATTERY 2030+ initiative, this topic aims at integrating advanced multi-scale computational modelling, materials synthesis and characterisation to perform autonomous material discovery that would accelerate by at least a factor of five the discovery of new sustainable and scalable redox active materials for RFBs. The successful projects should collaborate with the BATTERY 2030+ large scale research initiative and the developed battery materials acceleration platform (BIG-MAP) to ensure interoperability.

Project results are expected to contribute to all of the following expected outcomes:

- The creation of new tools and methods for significantly accelerating the development of RFBs materials, and the availability of validated models, in order to increase the competitiveness of the redox flow battery industry in Europe.
- The demonstration of AI-assisted materials discovery for redox flow batteries combining multi-scale computational modelling, materials synthesis and comprehensive characterization, ensuring integration with the BATTERY 2030+ MAP
- The integration of the AI-driven battery MAP with advanced robotics to enable closed-loop autonomous materials discovery and optimization.

- The acceleration of the development and design of any type of RFBs (aqueous/non-aqueous, conventional/hybrid – with insoluble species) and other flow battery materials through predictive physics- and data-driven modeling.

- Medium to long-term reduction of the cost of energy storage and increasing the competitiveness and sustainability of long duration energy storage.

Scope:

The objective is to develop, validate and demonstrate the use of a materials acceleration platform for RFBs combining multi-scale computational modelling, machine- and deep learning, automated materials synthesis and characterisation while also addressing aspects related to sustainability, cost and safety. In particular the proposal must (?):

- Develop and validate AI-assisted multiscale models (from material to system level) supporting the discovery of low-cost, sustainable and high-performance materials for RFBs (including redox couples, electrolyte formulations, membranes and electrodes). Scale bridging the different models from atomistic and mesoscale to multiphysics continuum macroscale models (cell level) is expected. Model should be suitable for different types of RFBs (e.g, aqueous/non-aqueous, conventional/hybrid).

- Develop and demonstrate an AI-driven MAP following the BATTERY 2030+ standards for the autonomous discovery of materials for RFBs, in particular redox couples and electrolytes, based on the computational multi-scale and data-driven models previously validated.

- Demonstrate a robotic prototype system that is capable of autonomous materials synthesis (for inorganic, organic or hybrid compounds), automated characterization, analysis, and validation that should be integrated with the AI-driven MAP for demonstrating closed-loop discovery. Automated lab-scale cell testing may be included for validating the MAP.

- Direct integration of information about sustainability, safety, cost and recyclability of the active materials in the battery MAP using available databases and generated datasets.

The validation of the AI-driven MAP must clearly demonstrate the potential to accelerate the discovery of high-performance materials for RFBs. In particular, possible targets for new materials are for example:

- Redox couples potential > 1.0 V;

- High reversibility/no overpotential between reduction and oxidation;

- Redox active materials with high solubility enabling ≥ 80 Ah/L electrolyte volumetric capacity and material utilization >80%;

- Redox active materials and electrolytes with capacity retention > 99.999 per cycle;

- Active material cost < 5€/kg enabling to reach a cost of storage below 0.05 €/kWh/cycle at least for storage durations up to X days (TBC);

- Avoiding use of fluorinated materials for membranes.

D2-1-15. Size & weight reduction of cell and packaging of batteries system, integrating lightweight and functional materials, innovative thermal management and safe by design approach

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology readiness level	Activities are expected to achieve TRL 6-7 by the end of the project

Expected outcomes:

Widespread electrification of mobile applications is necessary to achieve the goals of the European Green Deal. A competitive European battery value chain will have to deliver highly performant and safe battery systems in order to enable the necessary uptake of electrified mobility applications.

This topic focuses on delivering a safe by design approach for batteries reduced in size and weight which will deliver the performance necessary for mobile applications. The objective is to ruggedize energy storage packs by enlarging the environmental and operational conditions in which they can operate, while maintaining a high level of performance and achieving a reduction in the size and weight of the battery pack. Successful projects are expected to deliver on both following points:

- An increase of the net useful mass and volumetric energy density of the battery system by 30% compared to the state-of-the-art battery systems.

- The improvement of the safety by design measures throughout the battery lifetime and during operation.

Projects are furthermore expected to deliver innovative thermal management to increase performance for one of the following:

- Over all operational conditions;
- To enable fast charging requirements 10%-80% in 10 minutes maximum.

The solutions shall be demonstrated and validated at application level and should comply with all relevant standards.

Scope:

Projects must achieve size and weight reduction by integrating different technologies such as:

- Advanced cell technologies/generations, sensing technologies;
- The use of lightweight and multi-functional materials (including, but not limited to, the use of nanomaterials) and lightweight structures for battery casing.
- Improvement of the cell to system ration by adopting innovative packaging approaches.

Approaches to reduce the complexity of HV and BMS architecture and substitution by alternatives are within scope where relevant.

In addition, projects must improve battery performance and safety by demonstrating innovative thermal management systems which enhance fast charging capability high power application, safety and during operational lifetime (heating and cooling).

Proposals must also address innovations in the manufacturing processes and technologies that result size and weight reduction of the packs.

Finally, projects must enhance the safety throughout the full battery lifetime and for failure conditions by developing and demonstrating safe by design measures, such as:

- Thermal propagation measures;
- Fire retardant properties;
- Mechanical properties ameliorations.

The projects must focus on the battery system level, i.e., on the integration of battery cells into a battery system (e.g., a battery pack), considering mechanical, electrical and thermal aspects.

The integration of battery systems into larger systems of application (e.g., into vehicles structure) can be part of scope (e.g. cell to casing integration) as long as it can be demonstrated as a possibility to reduce overall packaging space, battery weight and battery performance improvement.

All solutions shall consider optimal design for manufacturing, end of life management and LCA analysis.

D2-1-16. Accelerated multi-physical and virtual testing for battery aging, reliability and safety evaluation

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	IA
Technology readiness level	Activities are expected to achieve TRL 6 by the end of the project.

Expected outcomes:

Projects are expected to contribute to all of the following outcomes:

- Shorter development time of battery cells and battery systems by reducing the experimental testing effort by at least 20% and thus reducing the overall costs and time in battery system development.
- Increased battery reliability and safety through better understanding of the ageing, reliability and safety-relevant mechanisms and phenomena.
- Uptake of zero emission vehicles and the deployment of stationary energy storage systems (ESS) through safer and cost-effective battery systems.
- Accelerated innovations in the battery eco-system through accelerated and more reliable verification and validation of advanced technological solutions contributing to increased use acceptance (safety & costs) and competitiveness of the European battery value chain.
- Standardisation of battery system testing & validation approaches focussing on the fusion of physical and virtual test methodologies.

Scope:

This call aims to reduce battery development costs, accelerate development speed and improve battery reliability including safety and life cycle performances by accelerated multi-physical and virtual testing. This call also aims to establish an EU wide safety classification system for safety evaluation for any battery chemistry. Current test strategies are still very time-consuming and costly due to an insufficient understanding of the impact of multi-physical operational loads (electric, thermal, mechanical, …), potential failure modes, ageing and mis-use on the safety and reliability of battery cells, modules and systems level. As a consequence, each physical phenomenon, known or anticipated, needs to be validated and verified subsequently by experimental means. Additionally, each variant (e. g. change in chemistry, configuration,…) or size of battery systems needs to be tested anew. To overcome these barriers, new multi-physical test strategies supplemented by virtual testing are required for deepening the understanding of factors impacting ageing, reliability and safety and their dependencies. This results not only in a better assessment of reliability and safety of batteries but also accelerates the development of new battery systems through more efficient and shortened test strategies, allowing the reuse of test results and for exploiting synergetic scaling effects between different battery systems.

This call complements the previous call HORIZON-CL5-D2-2022-01-07 focusing on the digitisation of battery testing. To differentiate, research activities should focus on the orchestration of accelerated testing and should result in a coherent test strategy from cell to system as much as possible, independent from chemistries and technologies applicable also to next-generation batteries. Proposals should address and demonstrate some of the below activities:

- Understanding and describing the impact of multi-physical operational loads, failure modes, ageing and mis-use on battery reliability and safety, highlighting the dependencies between them in order to design the most adequate testing methods and parameters. This includes deeper understanding of aging and degradation mechanisms induced by accelerated tests both on batteries safety performance and cycle-life to optimise the testing strategy. Assessment from the multi-physical modelling domain on the nature of the cell component's microscopic evolution to understand the achieved results at laboratory.

- Deriving advanced drive profiles and development of novel X-in-Loop (XiL) test environments for multi-physical and accelerated testing addressing electrical, thermal and mechanical loads at the same time. This includes the design of specimen mountings representing real-life conditions.

- Combining physics-based with data-driven test strategies enabling reliable virtual and distributed battery testing from cell to system also including the integration of the battery in specific applications (mobile and stationary) and its operation. This includes developing methodologies for accelerated model convergence mixing digital and XiL test results as well as decision-making algorithms for automized test definition and execution.

- Development of test strategies to exploit synergies between different battery chemistries, including next generation batteries, sizes and designs allowing to re-use or scale test results from cell level to system level.

- Development of simplified test strategies reducing the number of test and their complexity while improving battery safety and reliability. This includes on the fly testing protocols to facilitate/accelerate the parametrization and reduce the experimental load as well as the testing of aged or damaged batteries.

- Development of virtual methods to reduce the complexity of testing sample to sub-system DUTs (device under test) while full system is validated by virtual methods using the results from physical sub-system test.
- Development, exploitation, and harmonisation of advanced battery cell/pack measurement & diagnostic methods for enhancing the data depth and breadth over what is currently available from standard instrumentation. Development of performance indicators relating to battery degradation and safety and methods / requirements for correlating / validating digital models.
- Application of AI to the collected data at laboratory to redefine designed test matrix in order to improve the potential conclusions, reduce the testing time and effort and in general, to enhance the applied testing methodology.

Research activities should also lead to advance response strategies for damaged and aged batteries as well as should contribute to an EU wide safety classification system for safety. For the latter, the development of concepts for such a safety classification system are expected.

D2-1-17. Implementation and operational use of smart functionalities at cell and system level to advance safe operations

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology readiness level	Activities are expected to achieve TRL 6-7 by the end of the project

Expected outcomes:

The project must integrate smart sensing technologies to enhance the operational use and safety of the battery cells and systems. Those smart sensing technologies should be integrated into the battery management systems to reduce the total cost of the system.

Projects must contribute to all of following outcomes:

- Increase the battery operational use and lifetime by at least 20% through smart sensing technologies and control inside the battery cells and at battery system level.
- Optimisation of the Total Cost of Ownership (TCO) by at least 20% compared to state-of-the-art battery systems.
- At least 2 representative demonstrators at different levels (capacity, size, …), to demonstrate the manufacturability of the solution and where experimental results should be validated against the numerical simulations to further optimize the results numerically with lower cost and effort.
- The proposed technologies shall be in agreement with EUCAR HAZARD Levels.

Scope:

In battery electric vehicles, the battery system is a key part to achieve the key requirements such as range, acceleration, and safety. However, the safety of such ESSs has become a major issue while increasing the number of produced electric vehicles. At this stage, there are several types of hazards which may occur: chemical, electrical, thermal, a combination of them and other. Chemical hazards are mainly associated to electrolyte spillage and gas emissions. If two incompatible components are spilled, the chemical hazard might turn into a thermal hazard. For electric hazards, the main risk is linked to high voltage which is not usually relevant at cell level. However, the indirect hazard is the failure of electrical safety leading to a hazardous failure mode, like thermal runaway (TR) events. When a combination of chemical and electrical properties occurs, it may also lead to TR. In this case, the root cause requires prevention on different outcomes such as, electrical failure, mechanical abuse, and thermal abuse. The cell level is the best level to break the fire propagation chain, and therefore the main aspect for prospective research.

In order to minimize and prevent potential hazards that may occur at cell level, in addition to the use of safer materials, the development and integration of safety devices as CID, PTC, short circuit protection with integrated diagnostics are needed to monitor possible failures in early stage.

In the currently available battery systems, the level of implemented functionalities has been rather limited. The next-generation battery cells and systems will have smart multi-sensing technologies and functionalities to enhance the battery cell/system performances and safety and decrease the TCO. One of the major issues that reduce the lifetime of batteries is high operating temperature. Such a smart sensing technology would enable monitoring the inside temperature of individual cells of a system accurately to avoid battery operation in harsh high-temperature ranges that will result in thermal runaway. In addition to temperature monitoring, the development and integration of built-in cell sensors would allow to track vital parameters and prevent electrical failures, mechanical and thermal abuse.

Smart sensing technologies are required to obtain valuable information to evaluate cell and system performance. In this context, smart sensors should be placed at the electrochemical interface inside the cells to increase cell and system safety. This method would be more precise and robust than the existing technologies. During the operation of the cell and system under high charging/discharging, current rates, and short circuits, the temperature at the electrochemical reaction interface would be generated faster and needs to be monitored immediately. The smart sensing technology would be an early detector and protector for large battery systems by accurate measuring inside the cell and system. At the same time, in order to improve the cell, battery pack/system´s safety design, it is necessary to develop safety performance and failure prognosis models with the aim of precisely predict mechanical/electrical/thermal behaviour of the battery (including TR and propagation) and early detection of failing cells.

In addition, online adapting state functions (SoC, SoH, SoP, SoE, …) help monitor the health and safety states of the system. To fully supervise and control the cells in a battery system, monitoring the state functions in operation is mandatory. This will lead to control of the lifetime, quality, reliability, and safety of the system. The online adapting smart functionalities would be incorporated in the cell and system to follow the interphase and interface dynamics, structural changes, and multi-sensing technologies to supervise and control the cells in the system. For this reason, it is necessary to develop and enhance intelligent battery management systems (BMS) to monitor the SoX parameters. Intelligent BMS (online or offline) should also monitor each individual cell during storage, charging and discharging: the BMS needs to interact with sensors, shut-off and (dis)charge systems in the event of conspicuous behaviour.

In particular, projects must:

- Integrate smart sensing technologies to allow, in operation, adapting state functions for information transit from inside of the cell to the outside (to control the cells and system) and to the battery passport.
- Develop new non-destructive testing methods for SoX diagnosis of cell and system.
- Develop proper interfaces between the sensors, thermal management system and BMS.
- Develop safety devices: CID, PTC, short circuit protection with integrated diagnostics to detect and prevent possible failures.
- Develop safety performance and failure prognosis models to precisely predict mechanical/electrical/thermal behaviour of the battery and early detection of failing cells or systems (State of Safety models).

The smart functionalities must be applicable for predictive maintenance and end-of-life management (battery passport).

D2-1-18. Development of technical and business solutions to optimise the circularity, resilience, and sustainability of the European battery value chain

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of action	Research and Innovation Action
Technology readiness level	Activities are expected to achieve TRL 5 by the end of the project

Expected outcomes:

Projects must contribute to all of the following outcomes:

- Advancing circular and sustainable design and business practices relating to advanced batteries and associated value chains.
- Improving the life cycle sustainability performance of batteries produced in the EU, both in terms of reducing environmental impacts and maximising socio-economic benefits, including increased closed-loop practices.
- Improving batteries and their materials/components circularity through the promotion of more material efficient designs by enabling longer material/component lifetimes, improving added-value remanufacturing, refurbishing, repairing and recycling and ultimately decreasing the cost of using secondary materials/components in batteries.
- Enhancing EU strategic independence in terms of battery raw materials, the competitiveness of EU industry, and maximising socio-economic benefits at the EU level and beyond.
- Supporting the achievement of established EU recycling efficiency targets for 2030 and beyond.
- Enabling tools and best practice for multiple industry sectors in order to improve the EU industrial ambitions and global leadership beyond batteries

Scope:

This call will contribute to major EU policy ambitions, including achieving climate neutrality by 2050, and contributing towards the implementation of the European Green Deal and the Circular Economy Action Plan. Future batteries must demonstrate increased circularity and sustainability. Consideration of technical, environmental, social and economic factors is required. This call will not only enable technical advances (building on the work of previous calls) but also drive the development of new enabling business models and socio-economic tools. This scope will develop solutions to contribute towards the transition towards a circular economy, involving all stakeholders in the battery value chain. Circularity and sustainability should be assessable in a harmonized way based on reliable data and methods. Any improvement in terms of circularity at component and product system level must be accompanied by an improvement in terms of sustainability performance, i.e., a reduction of negative impacts of battery technologies, whilst maximising socio-economic benefits on society.

Proposals must cover all of the following points:

- Definition of assessment approaches for sustainable business models, including value proposition, value creation and delivery and value capture including environmental, social and economic dimensions. This activity will include analysis of best practice examples for sustainable business models.
- Development of sustainable business methods for technical, economic, and environmental evaluation of cycle life options: retrofit, second life, and recycling.
- Development of business methods to address outstanding issues, such as on-liability, across applications.
- Quantitative methodologies and tools that enable understanding whether recycling or second life is the optimum sustainable option, and at which level (pack, cell, electrode, material) recycling should be deployed.
- Optimisation of design and operation using LCA. Using high-quality data, exploring trade-offs between i) impacts at fabrication stage, ii) design for durability, iii) energy usage, iv) other functional aspects such as optimal sizing, hybridization, electronic management, thermal management.
- Innovations in battery design and architecture at all levels (system, pack, cell) supporting dismantling and recycling at the end of life. These could include the choice of materials and assembly methods and should not compromise the performance.
- Design of innovative sourced materials for improving sustainability in batteries by sustainable processes that avoid toxic/dangerous solvents and require controlled environments.
- Research and design of batteries from recycled materials and fully recyclable.

- Development of a central data information system and database (users of resources can see who offers which type and amount of battery system) and prototype Europe-wide information system for accident vehicles and their available battery systems for re-use.

Potential project collaboration is possible across other partnerships: 2ZERO, Clean Aviation, and Waterborne. Development of this scope was based on a consideration of the following previous calls (WP 2021-22):

- HORIZON-CL5-2021-D2-01-06: Sustainable, safe and efficient recycling processes (Batteries Partnership)
- HORIZON-CL5-2022-D2-01-07: Digitalisation of battery testing, from cell to system level, including lifetime assessment (Batteries Partnership)
- HORIZON-CL5-2022-D2-01-09: Physics and data-based battery management for optimised battery utilisation (Batteries Partnership)
- HORIZON-CL5-2022-D2-01-10: Streamlined collection and reversed logistics, fully automated, safe and cost-efficient sorting, dismantling and second use before recycling (Batteries Partnership)
- HORIZON-CL5-2021-D5-01-04: LCA and design for sustainable circularity - holistic approach for zero-emission mobility solutions and related battery value chain (2ZERO & Batteries Partnership)

Emerging breakthrough technologies and climate solutions

D2-2-1. Emerging energy technologies for a climate neutral Europe

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions

Technology Readiness Level	This topic focusses on technological concepts at low TRLs (TRL 3 or lower). Activities are expected to achieve TRL 4-5 by the end of the project.

<u>**Expected outcome:**</u> Project results are expected to contribute to **all** of the following expected outcomes:

- Demonstrate of knowledge and scientific proofs of technological feasibility of concepts on high risk/high return technologies for transition to climate neutral economy by 2050.
- Assessment of environmental, social, and economic benefits to contribute to R&I strategy.
- Contribution to establishing a solid long-term dependable innovation in Europe.

<u>**Scope:**</u>

This topic focusses on the development of novel bottom-up technological solutions with breakthrough potential across all parts of the **energy sector value chain**, as well as all energy-related aspects in the **transport sector**.

Projects supported under this topic **should** consider **one** of the following areas:

- Energy distribution;
- Long-term Energy storage.
- Novel energy generation methods

The **following areas should not be covered**, as they fall within either partnerships or other calls:

- Renewable energy technologies and renewable hydrogen production;
- Batteries.

The proposed topic must: i) present a robust research methodology and activities ii) establish the technological feasibility of the proposed concept iii) include a proper assessment of environmental, social, and economic benefits iv) consider the applicability of the proposed technology in various sectors.

To be considered, the proposed topics **must** fulfil the following conditions:

[insert minimum performance indicators here to ensure that topic does not fall outside of desired scope].

In developing its concept, the proposal **should** address the following aspects:

- Lower environmental impact (e.g. on climate change and pollution) quantified based on Life Cycle Assessment (LCA) framework;
- Barriers to the deployment of such technologies, including issues related to social acceptance or resistance to new energy technologies, related socioeconomic and livelihood issues globally;
- Prospective life cycle approach to be done with the relevant information that can be gathered at such TRL level.

Destination – Sustainable, secure and competitive energy supply

This Destination includes activities targeting a sustainable, secure and competitive energy supply. In line with the scope of cluster 5, this includes activities in the areas of renewable energy; energy system, grids and storage; as well as Carbon Capture, Utilization and Storage (CCUS).

The transition of the energy system will rely on reducing the overall energy demand and making the energy supply side climate neutral. R&I actions will help to make the energy supply side cleaner, more secure, and competitive by boosting cost performance and reliability of a broad portfolio of renewable energy solutions, in line with societal needs and preferences. Furthermore, R&I activities will underpin the modernisation of the energy networks to support energy system integration, including the progressive electrification of demand side sectors (buildings, mobility, industry) and integration of other climate neutral, renewable energy carriers, such as clean hydrogen. Innovative energy storage solutions (including chemical, mechanical, electrical and thermal storage) are a key element of such energy system and R&I actions will advance their technological readiness for industrial-scale and domestic applications. Carbon Capture, Utilisation and Storage (CCUS) is a CO_2 emission abatement option that holds great potential and R&I actions will accelerate the development of CCUS in electricity generation and industry applications.

This Destination contributes to the following Strategic Plan's **Key Strategic Orientations (KSO)**:

- *C: Making Europe the first digitally enabled circular, climate-neutral and sustainable economy through the transformation of its mobility, energy, construction and production systems;*
- *A: Promoting an open strategic autonomy*[42] *by leading the development of key digital, enabling and emerging technologies, sectors and value chains to accelerate and steer the digital and green transitions through human-centred technologies and innovations;*

It covers the following **impact areas**:

- Industrial leadership in key and emerging technologies that work for people;
- Affordable and clean energy.

The **expected impact**, in line with the Strategic Plan, is to contribute to *"More efficient, clean, sustainable, secure and competitive energy supply through new solutions for smart grids and energy systems based on more performant renewable energy solutions"*, notably through

[42] *'Open strategic autonomy' refers to the term 'strategic autonomy while preserving an open economy', as reflected in the conclusions of the European Council 1 – 2 October 2020.*

i. Fostering European global leadership in affordable, secure and sustainable **renewable energy technologies** and services by improving their competitiveness in global value chains and their position in growth markets, notably through the diversification of the renewable services and technology portfolio (more detailed information below).

ii. Ensuring cost-effective uninterrupted and affordable supply of energy to households and industries in a scenario of high penetration of variable renewables and other new low carbon energy supply. This includes more efficient approaches to managing **smart and cyber-secure energy grids** and optimisation the interaction between producers, consumers, networks, infrastructures and vectors (more detailed information below).

iii. Accelerating the development of **Carbon Capture, Use and Storage (CCUS)** as a CO_2 emission mitigation option in electricity generation and industry applications (including also conversion of CO_2 to products) (more detailed information below).

Global leadership in renewable energy

Renewable energy technologies encompass renewable electricity, renewable heating and cooling and renewable fuel technologies. They provide major opportunities to replace or substitute carbon from fossil origin in the power, heating/cooling, transportation, agriculture and industry economic sectors. Their large scale and decentralised deployment is expected to create more jobs than the fossil fuel equivalent and, especially, local jobs. Renewable energy technologies are the baseline on which to build a European and global climate-neutral future. A strong global European leadership in renewable energy technologies will pave the way to increase energy security and reliability.

It is imperative to enhance affordability, security, sustainability, and efficiency for more established renewable energy technologies (such as wind energy, photovoltaics, or bioenergy), and to further diversify the technology portfolio. Furthermore, advanced renewable fuels, including synthetic fuels and sustainable advanced biofuels, are also needed to provide long-term carbon-neutral solutions for the transport, energy consuming and energy-intensive industrial sectors, in particular for applications where direct electrification is not a technically and cost efficient option.

In line with the "do not harm" principle for the environment, research and innovation actions for all renewable energy technologies aim to also improve the environmental sustainability of the technologies, delivering products with reduced greenhouse gas emissions and improved environmental performance regarding water use, circularity, pollution, and ecosystems. For biofuels and bioenergy improving the environmental sustainability is associated to the biomass conversion part of the value chain and the quality of the product, while air pollution associated to combustion in engines falls in the scope of other destinations in Cluster 5 and other environmental aspects will be under Cluster 6.

Synergies with activities in cluster 4 are necessary for integrating renewable energy technologies and solutions in energy consuming industries and ensure that renewable energy solutions do not harm the environment. Complementarities with cluster 6 concern mainly biomass-related activities and with EIC low technology readiness level actions.

All renewable energy technologies are addressed as they have all a strong international market potential, and it will be coherent with the EU policy of industrial leadership worldwide.

Main expected impacts:

1. Availability of disruptive sustainable renewable energy and renewable fuel technologies & systems to accelerate the replacement of fossil-based energy technologies to achieve climate neutrality in the energy sector by 2050, without harming biodiversity, environment and natural resources.

2. Reduced cost and improved efficiency of sustainable renewable energy and renewable fuel technologies and their value chains.

3. Support de-risking of sustainable renewable energy and fuel technologies with a view to their commercial exploitation to contribute to the 2030 "Fit for 55" targets (in particular, 40% renewable energy share in the EU energy consumption, 2.2% advanced biofuels and 2.6% renewable fuels of non-biological origin shares in EU fuel consumption).

4. Better integration of sustainable renewable energy and renewable fuel-based solutions in all economic sectors, including through digital technologies.

5. Reinforced European scientific basis and European export potential for renewable energy technologies through international collaborations (e.g., the AU-EU Climate Change and Sustainable Energy partnership, the missions and innovation communities of Mission Innovation 2.0).

6. Enhanced sustainability of renewable energy and renewable fuels value chains, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities.

7. More effective market uptake of sustainable renewable energy and fuel technologies to support their commercialization and provide inputs to policy making.

8. Increased knowledge on the environmental impacts of the different renewable energy technologies along their lifecycle and value chains.

Energy systems, grids and storage

Main expected impacts:

1. Increased resilience of the energy system, based on improved and/or new technologies and energy vectors, to control the system and maintain system stability under difficult circumstances.

2. Increased flexibility and resilience of the energy system to plan and operate different networks for different energy carriers simultaneously in a coordinated manner that will also contribute to climate neutrality of hard-to-electrify sectors.

3. Innovative data-driven services for consumers that empower them to engage in the energy transition. Enhanced consumer satisfaction and increased system flexibility thanks to enabling consumers to benefit from new energy services and facilitating their investment and engagement in the energy transition.

4. Improved energy storage and energy vector technologies, in particular technologies for long-term storage of electricity and heat.

5. Foster the European market for new energy services and business models as well as tested standardised and open interfaces of energy devices through a higher degree of interoperability, increased data availability and easier data exchange.

6. More effective and efficient solutions for transporting and seamlessly integrating off-shore energy with new electricity transmission technologies, in particular using superconducting technologies, power electronics and hybrid Alternate Current – Direct Current grid solutions as well as MT HVDC (Multi Terminal High Voltage Direct Current) solutions.

7. Based on easy data-sharing, increased flexibility of the energy system to integrate renewables, and better predictability of return on investments in renewable and energy efficiency investments.

8. Speeding up of (from early-adoption to upscaling) of new digital technologies in the energy sector for the benefit of the energy transition.

9. Development of cyber-security and privacy tools and technologies tailor-made for the specific requirements of the energy system.

10. Development of technologies and systemic approaches that optimise energy management of IT technologies.

Carbon Capture, Utilization and Storage (CCUS)

Main expected impacts:

1. Accelerated rollout of infrastructure, in particular for CCUS hubs and clusters.

2. Continuing knowledge and best practice sharing activities, in particular on connecting industrial CO2 sources with potential bankable storage sites and installations using CO2, providing greater confidence for decision makers and investors.

3. Proven feasibility of integrating CO2 capture, CO2 storage and CO2 use in industrial facilities and to maximize the efforts to close the carbon cycle. Demonstrating these

technologies at industrial scale shall pave the way for subsequent first-of-a-kind industrial projects.

4. Reduced cost of the CCUS value chain, with CO2 capture being still the most relevant stumbling block for a wider application of CCUS. Develop innovative technology for CO2 conversion to reduce the need for pre-concentration and/or purification.
5. Adequate frameworks for Measurement, Monitoring and Verification (MMV) for storage and use projects, to document safe storage and for public acceptance of the technology.
6. Further research in DACCS and BECCS as CO2 capture technologies in combination with CO2 storage in order to deliver carbon removals.in view of achieving the net zero targets.
7. Assess the environmental impacts and risks, in the short, medium and long term, of CCUS technologies, with respect to the Do No Significant Harm principle, and to inter-generational solidarity.

Global leadership in renewable energy

Bioenergy

D3-1-1. Development of zero emission biomass CHP including carbon capture (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Advance the European scientific basis and increase technology competitiveness and technology export potential in the area of bioenergy.

- Reduced cost and improved technical performance and efficiency of bio-based CHP.
- Enhance sustainability of biomass based CHP by addressing socioeconomic and environmental sustainability, in particular in reducing emissions and air pollution and also addressing aspects of carbon reuse and circularity, also in particular in fossil economic areas in transition.

Scope:

Development of novel zero emission bio-based CHP technologies, which allow for highly efficient use of sustainable solid biomass residues, going hand in hand with zero emissions for particles and harmful gaseous emissions including NOx, SOx, aromatics etc. Flexibility for different biomass fuels and power/heat ratios featuring a wide range of temperatures for heat supply as well as technological interfaces for carbon capture as well as high cost-efficiency for the consumer are included.

The zero emission solution has to be implemented and assessed for the running CHP system Cost performance and environmental impact shall be assessed and improved in comparison to state of the art emissions capture and cleaning systems. Socio-economic aspects when applying such solutions in regions in transition from coal should be analysed and illustrated in the proposal.

D3-1-2. Development of Carbon fixation technologies for biogenic flue gases (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Availability of disruptive sustainable bioenergy technologies with negative carbon dioxide emissions.
- Increase technology leadership, competitiveness and technology export potential of European industry.

- Reduced cost and improved efficiency of sustainable bioenergy technologies and their value chains.
- Enhanced sustainability of bioenergy, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities.

Scope:

Development of biological and chemical solutions to use the effluent gases from bioenergy combustion systems and upgrade biogenic carbon emissions for the production of renewable energy carriers with renewable hydrogen for later reuse in the same system as feedstock for energy needs and achieving carbon circularity. Required are system components (e.g. catalysts), which are cost-effective and robust to flue gas toxicity and interface with the underlying bioenergy combustion system without compromising system performance in respect of technical efficiency and sustainability.

The effluent fixing solution has to be implemented in the conditions of the bioenergy combustion system and provide an integrated structure at the TRL requested. The reuse of the biogenic emissions based energy carriers shall be integrated. The assessment of the combustion gas upgrading shall be done and cost analysis of how this is a beneficial carbon capture and use solution shall be provided. Socio-economic aspects and impacts when applying such solutions in regions in transition from coal should be analysed and illustrated in the proposal.

CSP, Heat Pumps, Solar Thermal

D3-1-3. Novel thermal energy storage for CSP (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and innovation action
Eligibility conditions	The conditions are described in General Annex B.
Technology	Activities are expected to achieve TRL 4-5 by the end of the project –

Readiness Level	see General Annex B.

Expected Outcome: Project results are expected to contribute to some of the following expected outcomes:

- Improved dispatchability of concentrated solar power (CSP) plants
- Improved role of CSP plants in the energy system
- More compact CSP plant design
- Reduced greenhouse gas emissions
- Achievement of the CSP targets of the Strategic Energy Technology Plan

Scope:

Support will be given to novel thermal energy storage solutions for CSP plants. The thermal energy storage solutions proposed will have to achieve much higher storage densities than current commercial solutions (i.e. at least three times higher), while guaranteeing similar performance in terms of cycles.

The applicants should convincingly present that the storage solution that is developed has the potential to be applied at commercial level.

Projects should consider the possible impact on human health and assess the sustainability of the proposed solutions in environmental and socio-economic terms, taking into consideration the global value chains. Applicants are encouraged to consider a 'circularity by design' approach.

D3-1-4. Industrial manufacturing for lower-cost non-concentrating solar thermal components and systems (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation action

Eligibility conditions	The conditions are described in General Annex B.
Technology Readiness Level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Reduced greenhouse gas emissions;
- Reduced consumption of materials;
- Increased competitiveness of the European solar thermal manufacturing industry.

Scope:

Support will be given to innovative solutions to manufacture components and/or sub-systems and/or systems for non-concentrating solar thermal applications. The manufacturing solutions should increase the production output and reduce the cost vis-à-vis current production lines. The solutions should integrate quality controls and be flexible enough to adapt to various solar thermal applications.

The proposal should assess and optimize the requirements in terms of materials needed to produce the components and/or sub-systems and/or systems.

Applicants are encouraged to consider a 'circularity by design' approach.

D3-1-5. Innovative components and configurations for heat pump systems (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and innovation action
Eligibility conditions	The conditions are described in General Annex B.

Technology Readiness Level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Improved performance of heat pump components and/or systems;
- Reduced environmental footprint of heat pump components and/or systems;
- Reduced greenhouse gas emissions.

Scope:

Support will be given to innovative heat pumps and/or heat pump components. The innovative heat pumps and/or heat pump components should be more efficient, more reliable, safe, and affordable.

The proposal should assess and optimize the requirements in terms of materials needed to produce the heat pumps and/or heat pump components.

Applicants should apply a 'circularity by design' approach and assess the sustainability of the proposed solutions from a life cycle perspective. Among others, they should estimate the global warming potential expressed in $gCO2_e$/kWh of heat and/or cold delivered.

The requirements of the final users should be properly assessed (e.g., in terms of day-to-day operation, space requirements, noise, etc.).

D3-1-6. Retrofitting CSP plants by means of digital tools (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation action

Eligibility conditions	The conditions are described in General Annex B.
Technology Readiness Level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Improved performance of concentrated solar power (CSP) plants
- Reduced operation and maintenance costs of CSP plants
- Reinforced role of CSP plants in the power market
- Reduced greenhouse gas emissions
- Achievement of the CSP targets of the Strategic Energy Technology Plan

Scope:

Support will be given to the innovative application of digital tools (or to the application of innovative digital tools, or both) in currently operational CSP plants. Any type of application of the digital tools is in the scope (e.g., component control, performance measurement, self-diagnostic, ancillary services to the power system, etc.). Artificial intelligence techniques are also in the scope.

The digital tools should bring measurable benefits in terms of operation and maintenance of the CSP plant. Where thermal energy storage is available, the digital tools should also support night baseload generation.

The demonstration should span a continuous interval of at least six months covering all possible incidence angles of the direct solar radiation.

Geothermal Energy

D3-1-7. Advanced exploration technologies for geothermal resources in a wide range of geological settings (2023)

Specific conditions[2]	
Expected EU contribution per	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a

project	proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Technology Readiness Level	Up to TRL 5/6

Expected outcome:

Project results are expected to contribute to all of the following expected outcomes:

- Geothermal energy in a form that can be widely deployed and competitively priced, underpinned with reduced capital, operational and maintenance costs. Reduction of LCOE approaching SET Plan targets (actions should clearly justify estimated LCOE at project start and end);
- Performance and reliability improvement of shallow and/or deep geothermal systems;
- Reduced environmental impact;
- Reduced risk of seismicity;
- Increased citizen engagement for geothermal energy.

Scope:

To ensure a reliable pre-drilling assessment of geothermal resources, high resolution exploration methods and approaches are essential to minimize exploration risks. This will be achieved by a) The development and application of new tools and techniques coupled with innovative modelling and simulation techniques, increasing measurement precision and applying faster analysis of acquired data to achieve a feasible model of the reservoir. b) The update and improvement of state-of-the-art exploration techniques and methods to reduce the average cost for exploration while increasing the drilling success rate. Such progress must address in increasing detail the geological complexity of resources and increasing target depths

Validation of the technical and economic ability of innovative exploration approaches and tools to increase the precision for resource assessment, target definition of exploratory drilling and prediction of long-term reservoir performance. Moving beyond the state of the art by demonstrating the application of new tools, developing new approaches and taking advantage of improved software and computing power, the drilling success will be increased by 20% in 2025 and 50% in 2030 thereby reducing the exploration costs.

D3-1-8. Smart use of geothermal electricity and heating and cooling in the energy system (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Improved system integration of geothermal heat and power plants coping with changing demand for electricity, heat and cooling and intermittent renewable power generation;
- Enhanced operation flexibility of a geothermal heat and power plant by improving substantially key performance indicators: ramp rate & start-up time, power & heat operation range, overload capability;
- Implementation of smart control system aiming at optimizing plant operation by taking into account various control parameters (current and anticipated) such as demand (power & heat), price signals, renewable generation, etc.

Scope:

Demonstrate the technical and economic feasibility of responding to commands from a grid or network operator, at any time, to increase or decrease output ramp up and down. Demonstrating the automatic generation control (load following / ride-through capabilities to grid specifications) and ancillary services of geothermal power plants. Addressing flexible heating and cooling and electricity supply from binary cycles and EGS plants, including coupling with renewable energy sources;

Increasing variable demand of heating, cooling and electricity by integration of adequate installations and equipment such as heat pumps, ORC turbo-expanders, heat exchanger networks, hot and cold reservoirs (e.g. geothermal storage, UTES)

Actions will include impact on the development of transmission and distribution infrastructure, and the interplay with other flexibility options (e.g. demand-side management and storage), and test on dispatchability leading to AI-based smart thermal grids balancing generation and demand. The flexible generation should be able to provide additional services to the grid such as peak power, role in electricity balancing/reserve market.

D3-1-9. Innovative applications/integration of geothermal heating in industry (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- High integration of geothermal heat in industry;
- Enhanced operation flexibility of a geothermal heat by improving substantially key performance indicators: ramp rate & start-up time heat operation range for industrial uses.

Scope

Based on direct use of geothermal energy, the following must be achieved: demonstrate new heating concepts for industrial sectors which have to decarbonise their production lines using renewable systems; enable the smart use of thermal grids with emphasis on flexible supply of resources, adapted to different source temperatures and varying demand; and position geothermal utilization (including underground storage) as a crucial pillar for the (heat) transition of industrial energy systems. Activities include geothermal heat for industry and agriculture, underground thermal energy storage (UTES) including high-temperature storage, innovative and multiple uses for geothermal energy and side-products, balneological systems, and design and operation of geothermal doublets.

D3-1-11. Novel approaches for geothermal resource development using AI (2024)

Specific conditions	

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA (up to TRL 5)

Expected outcome: Project results are expected to contribute to [all/at least XX] of the following expected outcomes:

- Geothermal energy in a form that can be widely deployed and competitively priced, underpinned with reduced capital, operational and maintenance costs. Reduction of LCOE approaching SET Plan targets (actions should clearly justify estimated LCOE at project start and end);
- Performance and reliability improvement of shallow and/or deep geothermal systems development;
- Reduced environmental impact of geothermal plants;
- Reduced risk of seismicity;
- Increased citizen engagement for geothermal energy;
- Energy efficient, environmentally sound, and economically viable generation of electricity, and/or heating and cooling from geothermal resources in a wide range of geological settings, enabling geothermal energy development in new regions and supporting application concepts for local energy supply.

Scope:

The action aims at developing innovative methods and techniques using AI for reservoir development and exploitation in a wider range of geological settings.

The action covers the development of geothermal resources for generation of electricity, and/or heating and cooling in an energy efficient, environmentally sound and economically viable manner.

The action aims at using innovative approaches to

- reduce cost and risk of development;
- enhance exploitable geothermal resources;
- extend geothermal uses to complex and/or untested geological conditions.

Techniques of artificial intelligence and data-driven machine learning could be applied to improve greatly the mentioned issues.

Innovative methods such as robot drilling technologies or fast penetration rate technologies might be used to reduce cost and risk.

Novel production and stimulation technologies might allow to exploit more of the available geothermal resource. New geological environments which require additional reservoir performance improvement techniques may be developed for the geothermal use, fostering an unprecedented development of geothermal energy at European level (including Member States with low quality or presently absent resources).

Environmental impacts assessment and mitigation measures (e.g. induced seismicity, aeriform emissions, landscape footprint, chemical products, and corrosion) will be an integrated part of all development and exploitation.

Renewable Fuels

D3-1-12. Demonstration of advanced biofuel technologies for aviation and shipping (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Expand the technology portfolio for ready to pre-commercial plant investments in advanced biofuel technologies for aviation and shipping.
- Support de-risking the technology, boost scale-up of advanced biofuels for aviation and shipping and contribute to their market up-take.
- Respond to short and medium term needs for renewable fuels in aviation and shipping.

- Support better integration of advanced biofuel technologies in aviation and shipping.

Scope:

Demonstration of a diverse portfolio of pathways for the production of liquid jet-drop-in or liquid bunker drop-in advanced biofuels with reduced cost and GHG emissions from biogenic residues and wastes or microalgae through chemical, biochemical, biological and thermochemical pathways, or a combination of them. A significantly reduced cost than existing biofuels is expected. The sustainability and GHG reduction should be addressed on a life-cycle assessment basis.

D3-1-14. Demonstration of synthetic renewable fuel technologies for aviation and shipping (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Expand the technology portfolio for ready to pre-commercial plant investments in synthetic renewable fuel technologies for aviation and shipping.
- Support de-risking the technology, boost scale-up of synthetic renewable fuels for aviation and shipping and contribute to their market up-take.
- Respond to short and medium term needs for renewable fuels in aviation and shipping.
- Support better integration of synthetic renewable fuel technologies in aviation and shipping.

Scope:

Demonstration of a diverse portfolio of pathways for the production of synthetic renewable fuels for aviation and shipping from renewable energy, renewable hydrogen and renewable carbon /carbon oxides or renewable nitrogen/ nitrogen oxides, as for example renewable synthetic paraffinic kerosene, renewable methanol/methane and renewable ammonia. Pathways via production of renewable hydrogen from all forms of renewable energy (electricity, direct sunlight, heat) are in scope. Cost reduction compared to current state of the art via renewable electricity pathways and at least 70% GHG reduction should be shown. An assessment for the scalability potential of the technology, as well as for the overall energy efficiency, the GHG emissions and sustainability based on life cycle analysis should be included.

D3-1-15. Development of next generation advanced biofuel technologies (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Increase availability of disruptive emerging advanced biofuel technologies.
- Accelerate the readiness of cost-effective and highly performing future technologies of advanced biofuels for all economy sectors.
- Reinforce the European scientific basis and European technology export potential for advanced biofuel technologies.

Scope:

Development of next generation technologies for the production of novel advanced liquid and gaseous biofuels from biogenic residues and wastes or micro-algae open to all possible pathways. Focus shall be on the high conversion efficiency and the low to near-zero carbon emissions from the overall production. Overall, improve competitiveness and minimize GHG emissions through synergies with renewable hydrogen and other renewable energy technologies for processing energy. The new technologies should address specifically uses in fuel cells for all transport modes. The sustainability and GHG emissions should be assessed by an LCA and ways along the value chain to reduce them to and below net zero should be developed.

D3-1-16. Development of microalgae production and purification technologies for advanced aviation and maritime algal and direct solar fuels (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex B.

Expected outcome: Project results are expected to contribute to at least 3 of the following expected outcomes:

- Availability of disruptive sustainable renewable fuel technologies in order to accelerate the replacement of fossil-based energy technologies in aviation and shipping.
- Reduced cost and improved efficiency of sustainable microalgae-based renewable fuel technologies and their value chains.
- Increase technology leadership, competitiveness and technology export potential of European industry in possibly game-changing microalgae technologies.
- Enhanced sustainability of bioenergy, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities.
- Reinforced European scientific basis and European export potential for renewable energy technologies through international collaborations (e.g., the AU-EU Climate Change and Sustainable Energy partnership, the missions and innovation communities of Mission Innovation 2.0).
- Increasing the EU energy security and reliability by enlarging the renewable feedstock basis for aviation and maritime fuels as well as maintaining and fostering the

European global leadership in affordable, secure and sustainable microalgae-based renewable energy technologies.

Scope:

Development of microalgae and/or direct solar fuel production and purification technologies for making advanced aviation and maritime fuels from microalgae and/or direct sun use as techno economic feasible, cost-effective and sustainable option for large-scale use of microalgae-based and/or solar-based advanced fuels in aviation and maritime. Specific focus shall be on purification of microalgae biomass and delivery to advanced algal- based fuels and solar fuels for maritime and aviation. Acknowledging problems of culture or system contamination and the specific challenge of energy-efficient product purification, the specific techno-economic challenges of microalgae and/or direct solar fuels for renewable fuel production shall be addressed with novel and innovative technologies, by taking in particular into account effects on CAPEX, OPEX, energy efficiency, GHG balance and circularity of materials and process streams. Proposals should also address systemic constraints and opportunities for scaling-up algal-based and/or solar fuel technologies. Photovoltaic systems with separate fuel production and hydrogen as a fuel end-product is excluded. The sustainability and GHG reduction should be addressed on a life-cycle assessment basis.

D3-1-17. Demonstration of improved intermediate renewable energy carrier technologies for transport fuels (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Support de-risking the technology, boost scale-up of flexible intermediate bioenergy and synthetic renewable energy carriers and contribute to their market up-take.
- Respond to short and medium term needs for renewable fuels in transport.

- Increase flexibility, reliability and security of renewable energy supply in the transport sector.
- Increase available options for better integration of the energy system linking renewable energy production, storage and use via renewable energy intermediates.

Scope:

Demonstration of technologies for the production of advanced intermediate bioenergy and synthetic renewable energy carriers from biogenic residues and wastes, microalgae, CO2 or nitrogen and renewable hydrogen and all forms of renewable energy with reduced cost and GHG emissions. Proposals must demonstrate that conversion technologies have already reached pilot scale TRL 5. The finished quality should be suitable so that the intermediates can be either directly upgraded in existing refinery infrastructures and/or further purified and processed in existing chemical infrastructures to drop-in liquid and gaseous advanced biofuels and synthetic renewable fuels, or directly used for shipping propulsion or in other off-road transport. Examples are demonstration of production of bio-oils, raw alcohols, bio-liquids, biogas, syngas and thermally pre-treated solid biomass fuels from biogenic residues and wastes and microalgae oils through chemical, biochemical, thermochemical, biological, electrochemical, pathways, as well as synthetic renewable analogues. The integration of these intermediates in transport and their application in hard to electrify transport sectors should be presented. The logistics for transportation and storage of the intermediates should be addressed. The sustainability and GHG reduction should be addressed on a life-cycle assessment basis.

D3-1-18. Development of next generation synthetic renewable fuel technologies (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Increase availability of disruptive emerging synthetic renewable fuel technologies.
- Accelerate the readiness of cost-effective and highly performing future technologies of synthetic renewable fuels for all economy sectors.
- Reinforce the European scientific basis and European technology export potential for synthetic renewable fuel technologies.

Scope:

Development of next generation technologies for the production of novel synthetic renewable liquid and gaseous fuels from renewable feedstock for material regarding carbon, nitrogen and hydrogen and for energy in synergy with other renewable energy technologies for processing energy needs. Focus shall be on the high conversion efficiency, process energy efficiency and carbon emission neutrality from the overall production. Overall, improve competitiveness and minimize GHG emissions in the production process. Pathways via production of renewable hydrogen from all forms of renewable energy (electricity, direct sunlight, heat) are in scope. The new technologies should address uses in fuel cells for all transport modes. An assessment of the sustainability and the GHG emissions should be made based on a Life Cycle Analysis.

D3-1-19. Development of smart concepts of integrated bio-refineries for co-production of advanced biofuels, bio-chemicals and bio-materials (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Expand the portfolio of cost-effective advanced biofuel production concepts.
- Reduce cost, improve efficiency, support de-risking, to accelerate the availability of competitive and zero-waste advanced biofuel production concepts.

- Contribute to the Mission Innovation 2.0 mission of Renewable Fuels, chemicals and Materials through Integrated Biorefineries.
- Reinforce the European scientific basis and European export potential for renewable fuel production solutions through international collaborations.

Scope:

Development of zero-waste and neutral or negative carbon emission biorefinery concepts for enabling the production of low cost advanced biofuels through co-production of added-value bio-based products and bioenergy. Conversion of biogenic wastes and residues as well as algae and aquatic biomass through chemical, biochemical, biological, thermochemical pathways or combinations of them in highly circular processes are in scope. The integration design should include mass and energy flows, addressing the process heat and power needs by co-produced bio-heat and bio-power, capturing and reusing biogenic effluent gases and sequestering biogenic emissions, for example in the form of bio-char as soil amendment, such as to maximize overall material and energy efficiencies. An assessment of the feedstock cost supply at regional and local level and improvement of mobilisation patterns of the feedstock including via enabling technologies, such as digitalization, should be included. Socioeconomic and environmental sustainability shall be assessed on a life-cycle analysis basis. The advanced biofuels cost should aim to be reduced at parity with marketed biofuel equivalents or in the absence of these competitive to the fossil fuel equivalents. Pilot scale proof of concepts is required. International cooperation with Mission Innovation countries is expected.

D3-1-20. Improvement of light harvesting and carbon fixation with synthetic biology for renewable direct solar fuels production (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex B.

Expected outcome: Project results are expected to contribute to at least 3 of the following expected outcomes:

- Availability of disruptive and sustainable solar fuel technologies in order to accelerate the replacement of fossil-based energy technologies with more efficient use of primary solar energy in solar fuel production.
- Reduced cost and improved efficiency of solar-based renewable fuel technologies and their value chains by addressing rate-limiting steps in the solar fuels value chain.
- Increase technology leadership, competitiveness and technology export potential of European industry in possibly game-changing solar fuel and synthetic biological technologies.
- Enhanced sustainability of solar fuels, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities.
- Reinforced European scientific basis and European export potential for renewable energy technologies through international collaborations (e.g., the AU-EU Climate Change and Sustainable Energy partnership, the missions and innovation communities of Mission Innovation 2.0).
- Increasing the EU energy security and reliability by improving the solar fuel conversion efficiency as well as maintaining and fostering the European global leadership in affordable, secure and sustainable solar fuel technologies.

Scope:

Development of novel intracellular or in-vitro biochemical pathways for solar fuel production with increased efficiency in comparison to light and dark reactions of natural photosynthesis by synthetic biological approaches. The aim is to achieve a significant improvement of components of both, light harvesting and carbon fixation, which are rate limiting for the conversion of solar energy to renewable fuels. Proposals shall include case studies for analysing the potential and impact of the technology for future application at scale and analyse possible interfaces with other solar fuel technologies, with a particular focus on socioeconomic and environmental sustainability and cost-effectiveness. All relevant aspects of safety of the technology shall be addressed. Hydrogen as a fuel end product is excluded.

Hydropower

D3-1-21. Demonstration of sustainable hydropower refurbishment (2023)

Specific conditions[43]	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Activities are expected to achieve TRL 7-8 by the end of the project.

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Keep existing hydropower capacity fit for market and digital challenges of the future power market future power market.
- Increase technology leadership, competitiveness and technology export potential of European hydropower industry.
- Enhanced sustainability of additional hydropower installations, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities and in particular biodiversity.

Scope:

Demonstration of innovative solutions for sustainable hydropower refurbishment. With existing hydropower installation as a base, solutions shall demonstrate innovative technical solutions for refurbishment with increased sustainability of refurbished hydropower in terms of business models in changing power markets, including digital requirements. It is required to improve environmental sustainability with a particular focus on biodiversity including down-migration of aquatic organisms and sediment transport. Also additional benefits for society shall be addressed, e.g. for recreation. The innovative refurbishment solution shall go beyond increased efficiency, but lead to net-improvements in socioeconomic and environmental sustainability also considering future climate change adaptation needs.

[43] These are the absolute minimum conditions. Additional conditions may be added as needed (see section 1).

D3-1-22. Development of hydropower equipment for improving techno-economic efficiency and equipment resilience in refurbishment situations (2024)

Specific conditions[44]	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Activities are expected to achieve TRL 4-5 by the end of the project.

Expected outcome: Project results are expected to contribute to at all of the following expected outcomes:

- Keeping the availability of the existing hydropower fleet with an important role in the future power market.
- Increase technology leadership, competitiveness and technology export potential of European hydropower industry.
- Reduced cost and improved efficiency of refurbished hydropower installations.
- Enhanced sustainability of refurbished hydropower, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities and in particular biodiversity.

Scope:

Development of hydropower equipment for improving techno-economic efficiency and equipment resilience in refurbishment situations of existing hydropower plants, which are outdated in respect of efficiency, power market interfacing, climate change adaptation and environmental sustainability, in particular also in respect of biodiversity. In scope are novel technologies, which improve the efficiency and economic parameters of existing hydropower plants during refurbishment without requiring substantial modification of the hydraulic system and by implementing circularity by design, e.g. low-friction membranes and technical solutions that can minimize tear and wear in future operation modes. Solution should

[44] These are the absolute minimum conditions. Additional conditions may be added as needed (see section 1).

positively affect CAPEX and OPEX per kWh and also be compliant with improving the water quality of the underlying water body and in particular positively affect biodiversity.

Ocean Energy

D3-1-23. Demonstration of sustainable tidal energy farms (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA or PPI

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Demonstrated operation of multiple tidal energy devices in one farm.
- Derisking tidal energy technology development and increased bankability of tidal energy.
- Detailed analysis of current costs and potential future energy cost reduction pathways and the creation of a detailed business plan for full scale commercialisation.
- Increased availability and improved market confidence in the technology.
- Increased knowledge on positive and negative impacts of ocean energy on its environment.

Scope:

Demonstration of sustainable tidal energy pilot farms (minimum 4 MW installed capacity and at least 5 devices) in full operational conditions for long periods of time is essential to advance this sector. It is the way to bridge the gap from technology development to market development while reducing costs, reducing risks and attracting investors for future commercial projects. The tidal energy farms should be composed of several devices of the same series.

The tidal energy farms have to be connected to the electricity grid. To focus on the technologies with the greatest chances of success, the single tidal device to be used in the array deployment has been satisfactorily demonstrated at full scale before. The innovation component should mainly lie on the pilot farm subsystems and activities that enable a cost-effective and high performance pilot farm. Where established, stage-gate processes can help ensure that this approach is followed.

The project should deploy a tidal energy farm with a minimum capacity of 4 MW and operate the farm at least 2 years in the lifetime of the project. After the project it is expected that the farm will continue to be operated for at least 8 years with other EU/national/regional support.

The project should develop and execute an effective operation and maintenance programme.

Proposals are expected to address also all the following:

- Industrial design and manufacturing processes, circularity of (critical) raw materials, sustainability, scalability, installation methods, transport, operation & maintenance, supply chains and the related digital infrastructures.
- Projects are requested to demonstrate the technologies at sea while respecting existing environmental regulatory framework. Present an environmental monitoring plan to be implemented during the demonstration action. Environmental monitoring data should be open source and be shared with EMODNET and the IEA OES environmental task.

The project has to include a clear go/no go moment ahead of entering the deployment phase. Before this go/no-go moment, the project has to deliver the detailed engineering plans, a techno-economic assessment, including key performance indicators based on international recognized metrics, a complete implementation plan and all needed permits for the deployment of the project., a plan to achieve certification by an independent certification body before the end of the action, The project proposal is expected to clearly demonstrate a proposed pathway to obtaining necessary permits for the demonstration actions and allow for appropriate timelines to achieve these. The project is expected also to demonstrate how it will get a financial close for the whole action. Independent experts will assess all deliverables and will advise for the go/no-go decision.

The selected projects are expected to contribute and participate to the activities of the project BRIDGE[45] when relevant.

D3-1-24. Development of innovative power take-off and control systems (2023)

Specific conditions	
Expected EU contribution per	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a

[45] https://www.h2020-bridge.eu/

project	proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Demonstrated increased performance (>20%) and reliability of wave energy devices.
- Improved knowledge on how to operate wave energy devices, their availability, maintainability and survivability.
- Reduction of LCOE approaching SET Plan targets (actions should clearly justify the estimated LCOE at project start and end using a recognized calculation methodology).
- Reinforced industrial supply chain in Europe.

Scope: PTO and control systems (including gearboxes, electric generators and power electronics) are key subsystems of wave energy converters. PTO and control systems can be improved to increase the efficiency of the whole converter, to increase reliability and to avoid extreme events that might compromise device survivability. Control systems dynamically adapt to and mitigate the forces of the continually changing ocean conditions. This can prevent damage during extreme events, contribute to increased performance and the viability of the technology. The manufacturing and testing of prototypes are relatively costly, and it is imperative that data from the demonstration are available to avoid repeating early engineering mistakes. Verification in realistic environments at small scale for longer periods could make best use of scarce resources. Onshore testing and controlled lab testing can provide significant information and project should demonstrate that they can make use of existing test rigs or develop a test rig for the project, which can be used after the project by other developers. Development and demonstration of PTO technology should be combined with control strategies as their requirements are inherently coupled.

In the development of the PTO system the ‘circularity by design’ principle should be used.

D3-1-25. Demonstration of sustainable wave energy farms (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a

	proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA or PPI

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Demonstrated operation of multiple wave energy devices in one farm.
- Derisking wave energy technology development and increased bankability of tidal energy.
- Detailed analysis of current costs and potential future energy cost reduction pathways and the creation of a detailed business plan for full scale commercialisation.
- Increased availability and improved market confidence in the technology.
- Increased knowledge on positive and negative impacts of ocean energy on its environment.

Scope:

Demonstration of sustainable wave energy pilot farms (minimum 2.0 MW installed capacity and at least 5 devices) in full operational conditions for long periods of time is essential to advance this sector. It is the way to bridge the gap from technology development to market development while reducing costs, reducing risks and attracting investors for future commercial projects. The wave energy farms should be composed of several devices of the same type.

The wave, energy farms have to be connected to the electricity grid. To focus on the technologies with the greatest chances of success, the single wave energy device to be used in the array deployment has been satisfactorily demonstrated at full scale before. The innovation component should mainly lie on the pilot farm subsystems and activities that enable a cost-effective and high performance pilot farm. Where established, stage-gate processes can help ensure that this approach is followed.

The project should deploy a wave energy farm with a minimum capacity of 2 MW and operate the farm at least 2 years in the lifetime of the project. After the project it is expected that the farm will continue to be operated for at least 8 years with EU/national/regional support.

The project should develop and execute an effective operation and maintenance programme.

Proposals are expected to address also all the following:

- Industrial design and manufacturing processes, circularity of (critical) raw materials, sustainability, scalability, installation methods, transport, operation & maintenance, supply chains and the related digital infrastructures.
- Projects are requested to demonstrate the technologies at sea while respecting existing environmental regulatory framework. Present an environmental monitoring plan to be implemented during the demonstration action. Environmental monitoring data should be open source and be shared with EMODNET and the IEA OES environmental task.

The project has to include a clear go/no go moment ahead of entering the deployment phase. Before this go/no-go moment, the project has to deliver the detailed engineering plans, a techno-economic assessment, including key performance indicators based on international recognized metrics, a complete implementation plan and all needed permits for the deployment of the project., a plan to achieve certification by an independent certification body before the end of the action, The project proposal is expected to clearly demonstrate a proposed pathway to obtaining necessary permits for the demonstration actions and allow for appropriate timelines to achieve these. The project is expected also to demonstrate how it will get a financial close for the whole action. Independent experts will assess all deliverables and will advise for the go/no-go decision.

The selected projects are expected to contribute and participate to the activities of the project BRIDGE[46] when relevant

D3-1-26. Critical technologies for the future ocean energy farms (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

[46] https://www.h2020-bridge.eu/

- Demonstrated increased performance with the focus on sustainability, operation and maintenance of ocean energy devices.
- Improved knowledge on how to operate ocean energy devices, their availability, maintainability, reliability, survivability and sustainability.
- Reduction of LCOE approaching SET Plan targets (actions should clearly justify the estimated LCOE at project start and end using a recognized calculation methodology).
- Reinforced industrial supply chain in Europe.

Scope:

- Components and systems used in ocean energy devices need to be resistant to corrosion and the heavy loads they are subject to. Develop new materials with improved fatigue, damping, stiffness, sustainability and bio-fouling management or other cost-reducing characteristics. Materials such as reinforced concrete, polymers, composites, and concrete-steel/composite-steel hybrids systems have demonstrated some advantages in other offshore sectors, such as reduced costs. Demonstrating the potential benefits of these new materials in ocean energy converters, moorings and foundations whilst ensuring structural integrity, durability and circularity is required.
- Advance the design of sustainable tailored mooring and connection of electrical or other power transmission systems for floating wave and tidal devices. Advance combined mooring and electrical connectors or hydraulic power transmission to reduce component cost and number of connection operations, included in systems for sharing an anchor between devices in arrays. Develop novel systems for safe and quick connection/disconnection that do not require large vessels and/or diving teams.
- Instrumentation for condition monitoring and predictive maintenance of ocean energy devices. Apply recent advances in condition and structural health monitoring from other sectors to ocean energy – particularly those currently developed for offshore wind. Apply latest sensor technology to existing ocean energy deployments. Document and share experience on sensors performance and reliability, and methods for adapting them to the harsh ocean energy environment. Improve transmission or storage of data collected from sensors, such as underwater data transmission.
- Use of AI in ocean energy technology development. Develop or apply advanced simulation of ocean energy systems. Use of big data with analysis of data streams, application of big data methods and machine learning, including artificial intelligence, or digital twin models for the design, installation, operation and decommissioning of ocean energy devices.

Photovoltaics

D3-1-27. Advanced concepts for crystalline Silicon technology (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

1. PV modules with higher efficiencies and lower costs.
2. Lower environmental impact with efficient and optimised use of materials/resources.

Scope:

Develop nanophotonic structures to maximize absorption, enabling reduced silicon consumption and higher efficiencies; advanced low-cost surface passivation and novel passivating contacts; novel heterojunctions; innovative texturization and light-trapping concepts for thin and ultrathin solar cells; direct bandgap architectures for very high efficiencies and/or thinner cells.

D3-1-28. Large Area Perovskite solar cells and modules (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.

Type of Action	IA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

1. Increase the stability, efficiency and minimise the environmental impact of Perovskite PV.
2. Enlarge with novel perovskite device architectures the integration and application possibilities of PV technology.
3. Increase the potential for industrial production and commercialisation of perovskite PV creating a competitive technological know-how for the European PV industrial base.

Scope:

The record power conversion efficiency of small-area perovskite solar cells has impressively exceeded 25%. For commercial application, a large-area device is the necessary next step. However, there is still a certain efficiency gap between the large and small size. To minimise this gap it necessary to:

- Develop/Demonstrate a scalable method for the deposition of high-quality large-area perovskite films.
- Develop/Demonstrate fabrication of large-area charge transporting layers and electrodes.

In addition to improving the efficiency for commercial development of Perovskite PV, the stability is another challenge that urgently needs to be addressed.

- Identify and tackle complex stability issues at the module level (related to the processes involved in the fabrication).
- Perform outdoor field performance testing of the perovskite modules.

D3-1-29. PV integration in buildings and infrastructure (2023)

Specific conditions	
Expected EU	The Commission estimates that an EU contribution of XX million

contribution per project	would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Eligibility conditions	The conditions are described in General Annex B.

<u>Expected Outcome</u>: Project results are expected to contribute to [all/some] of the following expected outcomes:

1. Demonstrate economic and sustainable PV integration in the built environment and infrastructure.
2. Establish enhanced structural collaborative innovation between PV companies and the (building) construction sector.
3. Contribute to the Renovation Wave, the Mission on climate-neutral and smart Cities and the New European Bauhaus initiative.

<u>Scope</u>:

Demonstrate yield-friendly colouring techniques, structural flexibility, module flexibility, suited voltage levels, the use of and combination with (building) materials other than glass, new encapsulation technologies, and an overall high aesthetical value that addresses the requirements of architects and designers.

Demonstrate resilience against partial shading, the interconnection of PV modules that have different sizes, specific thermal control solutions, service life/easy replacement, security and simplicity of maintenance, software control for quick detection of faults, module substructures and fixing systems to enhance both PV system aesthetics and electricity yield.

Decrease costs and enhance quality, reliability and sustainability with new approaches for both PV module and BOS with the development of industrialized mass-production of customized products and development of prefabricated solutions that incorporate an integrated life cycle approach.

Develop energy integration concepts and social behaviour to maximize the energy matching between PV production and local buildings consumption, supported by new tools and business models to ensure their economic effectiveness.

Demonstrate integration of PV design and manufacturing within the construction value chain with appropriate consideration to building standards and contribution to standardization activities.

Form alliances between all stakeholders (PV and building sectors, investors, owners, architects, installers) to tackle a number of educational and regulatory barriers that still hinder the development of BIPV with the goal of promoting new concepts/schemes and business models for an active role of integrated PV in renovation and construction.

D3-1-30. Floating PV Systems (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Expand the potential application and minimise the environmental impact of Floating PV technology for inland and offshore waters.

Scope:

Floating PV (FPV) has huge potential in areas where difficult terrain or land constraints make ground-mounted systems impractical. However, FPV also face a plethora of challenges for various environmental conditions such as wind, wave, currents and water level variations that could adversely affect the electrical output and life of the plant.

Develop (and verify) predictive yield models including dynamic behaviour of the PV including floats, temperature effects and wave induced mismatch losses, depending on the application environment (wave height class).

Demonstrate advanced module and system concepts for electrical output optimisation considering the disturbance of environmental factors to the electrical output characteristics of PV modules and systems.

Demonstrate system components that satisfy the structural and functional requirements for the entire lifecycle (degradation, environmental stress cracking, UV stabilisation, exposure to water, salinity, humidity, algae growth, toxicity) but also demonstrate low impact on ecosystem biodiversity and satisfy end-of-life recycling aspects.

D3-1-31. Solar Systems for Industrial Process Heat and Power (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Energy efficient solar resource integration in the industrial sector for achieving low-carbon, pollution-free production systems.

Scope:

Industrial processes need considerable amounts of heat and power. Much of the demand for process heat, roughly 50% among the most energy-intensive manufacturing industries, including food and beverages and pulp and paper, occurs at temperatures of 300 °C or less. The solar cogeneration of electricity with high-temperature process heat can be an effective way to transition to clean energy sources and displace conventional fossil fuel use in industry. This high exergy output would allow a useful integration of solar in many industrial processes.

Demonstrate a system that generates solar electricity and high-temperature heat (PV, solar thermal, hybrid) in a modular, low footprint, low cost, and high-efficiency design. Optimize the manufacturing processes, process control, and heat recovery to reduce process power and heat demand to its practical minimum for an energy efficient solar energy supply (possibly including storage) investment.

Demonstrate the potential of photovoltaics (PV), solar thermal, and hybrid approaches that produce electricity and/or heat to power a broad range of manufacturing end uses.

D3-1-32. Operation, Performance and Maintenance of PV Systems (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

1. Increase PV system performance, reliability, security and flexibility under various topology and operating conditions with enhanced digitalisation
2. Increase the contribution of PV electricity into the European energy system

Scope:

Demonstrate smart communication tools (5G) and application of Machine Learning to predict degradation/failure propagation, for preventive maintenance, (solar radiation and) forecasting, nowcasting, user behaviour and modelling of the entire electricity system. Application of advanced methods and novel indicators for PV plant performance analysis.

D3-1-33. Rethinking module design (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

1. Reduction in the use of scarce metals (without compromising device performance) towards sustainable PV manufacturing at the multi-TW scale
2. Reduction in the use of non-recyclable materials
3. PV modules with enhanced lifetime, reliability and sustainability

Scope:

As the PV industry heads towards multi-terawatt scale of annual production, module design should be looked over to minimise (scarce) material use, to improve efficiency and energy yield and increase lifetime (minimising defects and degradation mechanisms), while implementing the “circularity by design” concept.

- Develop metallization and interconnection technologies with reduced silver and bismuth consumption and/or alternative silver-free metallization and interconnection technologies; investigate the possibility of using abundant low-temperature solder alloys.
- Develop indium-free transparent conductive oxide layers (TCO) for Silicon Heterojunction (SHJ) and future tandem solar cells.
- Develop a new generation of front and back-sheet materials/coatings and encapsulation methods for recycling/reuse.

D3-1-34. Alternative equipment and processes for advanced manufacturing of PV technologies (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Eligibility conditions	The conditions are described in General Annex B. - Application of Art 22.5 (tbc)

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

1. Contribute towards establishing a solid European innovation and production base
2. Reduce the CAPEX and OPEX in the PV solar production chain, ultimately leading to cheaper modules and lower LCOE
3. Reinforce the sustainability of the EU PV value chain

Scope:

Demonstrate alternative processes and equipment for PV manufacturing with reduced CAPEX, OPEX, and material consumption.

Increase the productivity and sustainability of large-scale PV manufacturing equipment and processing, for example by the enhancement of: i) throughput (e.g. wafers/time or module area/time) ii) yield (process & quality control) iii) availability (e.g. optimisation of uptime & service time) and iv) quality control.

D3-1-35. Low power PV (2024)

Specific conditions	
Expected EU contribution per	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless,

project	this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Increase the potential of PV for low power, low irradiation applications (harvesting energy in low light intensity and/or artificial light conditions)

Scope:

Photovoltaic energy harvesting in low light conditions such as indoors, or under artificial or diffuse light can be used to power sensors, as well other low-power electronics. Efficient energy harvesting combined in an energy system with storage unit and low power electronics, can enable a wide range of applications, for example autonomous sensors, domotics, remote monitoring, and portable devices in general.

Proposals should identify novel PV materials, PV architectures and suitable substrates for the specific low power applications that take into account the light intensity, light spectrum and application itself. PV system performance must be tailored to meet the application-specific power and energy requirements.

The proposal should include a clear definition of the use case and lifecycle considerations, e.g. business models, circularity by design aspects, certification, etc.

D3-1-36. PV-integrated electric mobility applications (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

1. Open new market opportunities for Vehicle-Integrated Photovoltaics (VIPV) in road transport.
2. Reduce usage of the electricity grid and increase the range of electric vehicles.
3. Cost and energy efficient climate-neutral road transport.

Scope:

PV technology can contribute to improved features of electric mobility systems not just in terms of CO2 (and air-pollution) emissions reduction but also regarding product aesthetics and user experiences.

- Develop Vehicle Integrated PV concepts (VIPV),
    - including different cell, interconnection and encapsulation technologies (with high efficiency under bad lighting conditions) having a flexible design (size, shape/curvature, lightweight, aesthetics) with PV providing a significant part of the vehicle's energy consumption under various climatic conditions.
    - considering cost optimisation and environmental friendliness of VIPV integration that meets automotive specifications and safety/repair/maintenance standards (crash, emergency, resistance, reliability, long-lasting lifetime and high number of lifecycles) for various types and vehicle uses.
    - and a vehicle usage model to maximise the ratio of using solar power and performance for VIPV, considering various climatic conditions and uses while minimising energy losses.
- Develop PV Charging Stations (EVs, electric buses, etc.) able to provide a significant part of the charging demand despite the PV intermittence, guarantee the balance of the public grid, and reduce the public grid energy cost, with optimal charging/discharging start time for EVs, through its arrival time, departure time, initial and final state of charge (SOC), to achieve peak shaving and valley filling while reducing the costs of energy from the public grid.

D3-1-37. Innovative, Community-Integrated PV systems (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

1. Increase the profitability and penetration of PV systems in renewable energy communities.
2. Engage actively citizens and communities in the clean energy transition.

Scope:

Planning, plant optimisation tools, advanced installation criteria, construction issues to increase yield and thus economic performance of PV systems in the built environment. Implementation of collective self-consumption schemes, design, simulation, integration with storage, interaction with electric mobility.

D3-1-38. Resource Efficiency of PV in Production, Use and Disposal (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	CSA
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

3. Reduce the environmental footprint associated to PV technology deployment across all the phases of the system lifetime (production, installation and end of life).
4. Define design and processing guidelines to optimally address circularity of PV systems for one or several PV technologies (silicon, thin film, organic PV, perovskite PV, etc.).

Scope:

To identify the main areas of improvement for the environmental footprint and resource efficiency of PV, it is necessary to regard the technology's entire lifecycle. Using Life Cycle Assessment (LCA), important knowledge can be gained as to which processes and materials contribute most to the overall environmental footprint. The lifecycle thinking also aids in identifying key candidates to reduce the use of resources from the design phase. Although it seems self-explanatory that reduction/substitution or efficient use of critical materials lead to improved environmental impact, it is of course essential that this do not adversely affect the function of the technology.

For a renewable energy technology to be successful, it needs to have a strong net positive energy balance. This implies that the energy payback time of systems needs to be short, the carbon footprint needs to be reduced, the use of local materials to reduce transport costs in systems must be increased, the use of hazardous materials needs to be avoided, and systems and system components need to be designed in a way that encourages recycling and decreases material usage.

Wind Energy

D3-1-39. Digital twin for forecasting of power production to wind energy demand (2023)

Specific conditions	

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcome: Project results are expected to contribute to [all/at least XX] of the following expected outcomes:

- Precise energy yield prediction to ease investment decisions based on accurate simulations
- Enhanced digitisation of wind energy sector

Scope:

The expected growth of offshore wind energy is enormous and many new wind parks are planned for the coming years. Experience from the existing wind farms shows the importance of a proper distribution of the wind turbines as well their efficient interconnection within the farm. In addition, bringing wind farms together into clusters toward a wind power plant concept might induce long distance negative interaction between the farms, reducing their expected efficiency. The objective of this topic is to develop new digital twins to optimise the exploitation of individual wind farms as well as wind farm clusters, in view of transforming them into virtual power plants. Such a digital twin should integrate:

- Weather forecast models;
- Spatial modelling: medium (within wind farms) to long distance (between wind farms) wake effects;
- Interconnection optimisation: to satisfy grid connection requirements and provide ancillary service;
- Include predictive maintenance and conditional monitoring, and
- Precise energy yield prediction to ease investment decisions based on accurate simulation.

The project should focus on offshore wind power systems and make optimal use of previously developed models. Validation should be carried out with data of existing wind farms,

To support rapid market uptake, widespread application and further innovation based on the developed solutions, projects are invited to use Open Source solutions when appropriate, and clarify in case they choose not to use Open Source, so that they can support the planning of future large scale offshore wind installations.

Selected projects will be required to share knowledge. Projects will acquire performance-related data in a standard format to support advancement of R&I for the benefit of all projects through Artificial Intelligence methods. This data and relevant meta-data may be shared with other projects (not supported through Horizon Europe, including relevant projects supported through the Innovation Fund) on reciprocal terms and with EU-based researchers having a legitimate interest. The selected projects shall cooperate with the project selected under the call [CSA for data-sharing between renewable energy R&I project to advance innovation and competitiveness].

The selected projects are expected to contribute to relevant BRIDGE[47] activities.

D3-1-40. Minimization of environmental, and optimization of socio-economic impacts in the deployment, operation and decommissioning of offshore wind farms (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected Outcome: Project results are expected to contribute to some of the following expected outcomes:

- Innovative and cost-effective solutions for the construction and decommissioning of offshore wind farms.
- Implementable, simple and measurable criteria to assess, at the tendering stage of the project, the sustainability and environmental (positive) impact of offshore wind farms.
- Validated design tools for the planning of offshore wind farms minimising impact on the local environment (noise, impact on sea bed, visual effect, effects on marine

[47] https://www.h2020-bridge.eu/

life and other species), including floating turbines (e.g. the environmental impacts of fixing/anchoring techniques).

- Enhanced sustainability by addressing economic, social and environmental aspects (air pollution, waste management, job opportunities, wildlife concerns, etc.) of offshore of offshore wind farms.

- Enhanced overall sustainability of large-scale production of offshore wind farms based on mainstreamed Life Cycle Analysis addressing social, economic and environmental aspects, as well as improved circularity of offshore wind turbines.

Scope: The aim is to develop and promote the use of modelling tools and objective holistic assessment metrics for realistic in-depth analysis of (cumulative) impacts of wind installations on the environment and on local communities and to integrate these in design tools for the deployment of offshore wind farms. It will be as well necessary to find innovative solutions to minimize the environmental impact during all stages of the life-cycle of offshore wind farms but especially for the construction and decommissioning phase.

The action is expected to

- develop design tools which can be used for the planning of offshore floating and fixed-bottom wind farms with the focus to minimize the overall life-cycle environmental impacts, reducing carbon footprint of the offshore wind plants across the life cycle, from construction to end of life and reduce the environmental impact in each consecutive step. The tool should make use of existing data of environmental impact studies and should be easy to customise considering different sea basin biodiversity characteristics and new available data. For that reason a strong participation/commitment of industry players to ensure that inventory data from industry of the components is used in the analyses is required. The aim is to enhance sustainability by addressing economic, social and environmental aspects (air pollution, waste management, job opportunities, wildlife concerns, etc.) of offshore of offshore wind farms.

- develop innovative and cost-effective solutions (innovative processes, supply chains, materials for construction, ….) for all phases of the life cycle of offshore wind farms but especially for the construction and decommissioning phase of offshore wind farms with the aim to reduce the environmental impact as much as possible in these stages of the life cycle of offshore wind farms.

The action will deliver recommendations for implementable and measurable criteria to assess, at the tendering stage of future project, considering the sustainability and environmental (positive) impact of offshore wind farms.

In order to increase the integration of the design tools and the innovative solutions, it is important that consortia engage all different stakeholders like regulatory bodies, industry, governments and citizens.

This R&I need is identified in the offshore renewable energy strategy (COM(2020) 741 final) that commits the Commission to 'carry out an analysis of costs and impacts of the decommissioning of offshore installations, with a view to assessing whether, both for the dismantling of the existing installations and for future decommissioning activities, EU-wide legal requirements are needed to minimise environmental, safety, economic impacts'.

D3-1-41. Critical technologies for the offshore wind farm of the Future (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcome: Project results are expected to contribute to [all/at least XX] of the following expected outcomes:

- Improved performance of offshore wind turbines and efficient use of the marine space;
- Reinforced European offshore wind turbine value chain, supporting local companies and creating local jobs and skills;
- Reduced dependency on primary raw materials;
- Reduction of LCOE approaching SET Plan targets.

Scope:

The objective is to bring major innovations in the design and manufacturing of large offshore wind farms, aiming at >15 MW for fixed bottom offshore applications and >10 MW for floating offshore installations. Particular attention should be paid to substantially reducing the wind turbine mass (rotor/nacelle/tower) as well on marine-compatible substructures, including floating platforms. Innovations such as compact generators, smart blades, and reliable drive trains can be investigated alongside new turbine designs. Innovative low-cost substructures with suitable hydro-dynamic properties should be developed using long-lasting, anti-fouling, corrosion resistant materials with high damping properties.

The innovations should contribute to sustainability considering circularity in the design phase, less (or no) use of (critical) raw materials, and decreasing environmental and social impact.

Such development will allow further deployment of offshore wind energy conversion systems and dramatically increase the offshore wind potential while reducing public acceptance barriers (noise, visual impact).

The active participation of key industrial partners and technology suppliers is essential to form a multisectorial, multidisciplinary consortium able to achieve the full impact of the project.

This R&I need is identified in the offshore renewable energy strategy (COM(2020) 741 final) that describes that further R&I action is needed in critical raw material substitution, reducing the environmental impacts of offshore technologies, and job creation.

D3-1-42. Critical technologies to improve the life-time, efficient decommissioning and increase the circularity of offshore and onshore wind energy systems (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Improved overall life time, reliability, recyclability, sustainability, operability and maintainability of onshore and offshore wind turbines and substructures;
- Mainstreamed affordable high life-cycle performance, and improved circularity of wind turbine components;
- Open new markets in wind turbines recycling.

Scope:

Innovative technologies to improve the life-time, efficient decommissioning and increase the circularity of wind energy systems. Project can address one of the following points:

- development of improved, more dam-age-tolerant materials (composites and adhesives)
- The development of improved manufacturing procedures and design methods for wind turbine components (e.g. incorporating pre-cast carbon-fibre parts into blades)
- The development of materials and interfaces for joints of major load-carrying parts like main spars (split blades)
- The development of bio-based fibres and resins with improved mechanical properties
- Life time extension by innovative repair solutions for dynamic cables, wind turbine components like blades and drive train.
- New condition monitoring technologies to improve operation and maintenance methodologies.
- New efficient recycling technologies for wind energy components.
- Alternatives in materials/new advanced materials (e.g. natural fibre composites).

But can consider other solutions.

This R&I need is identified in the offshore renewable energy strategy (COM(2020) 741 final) that commits the Commission to 'systematically integrate the principle of 'circularity by design' into renewables research & innovation'.

D3-1-43. Demonstrations of innovative floating wind concepts (in support of the offshore renewable energy strategy) (2024)

Specific conditions[3]	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Demonstrated innovative pilot projects;
- Knowledge about design, construction, and operation and maintenance of floating wind farms;
- Improved overall reliability, installability, operability and maintainability of floating offshore wind turbines;
- Demonstrated efficient, low-cost and sustainable emerging technologies for floating wind turbines;
- Reinforced European offshore wind turbine value chain and skills.

Scope: The overall aim is to accelerate the cost-effective construction and deployment of floating wind farms, facilitating their rapid and sustainable deployment across Europe and lower their overall costs. Projects are expected to

- Demonstrate innovative floating vertical or horizontal axis offshore wind energy platforms (>4MW total capacity for HAWT and >2MW total capacity for VAWT) in real sea conditions for long periods of time (12-24 months) providing invaluable learnings regarding performance, reliability, availability, maintainability, survivability and environmental impact.
- Develop and implement pilot projects for floating wind by identifying the best existing practices and the remaining knowledge gaps. This could be achieved by deepening the European expertise in the construction, maintenance and operability of offshore wind turbines.

Proposals are expected to address also all the following:

- Industrial design and manufacturing processes, circularity of (critical) raw materials, scalability, installation methods, transport, operation & maintenance, supply chains and the related digital infrastructures.
- Projects are requested to demonstrate the technologies at sea while respecting existing environmental regulatory framework. Present an environmental monitoring plan to be implemented during the demonstration action. Data on environmental monitoring have to be shared with EMODNET and IEA OES Environmental task.

The project has to include a clear go/no go moment ahead of entering the deployment phase. Before this go/no-go moment, the project has to deliver the detailed engineering plans, a techno-economic assessment, including key performance indicators based on international recognized metrics, a complete implementation plan and all needed permits for the deployment of the project., a plan to achieve certification by an independent certification body before the end of the action, The project proposal is expected to clearly demonstrate a proposed pathway to obtaining necessary permits for the demonstration actions and allow for appropriate timelines to achieve these. The project is expected also to demonstrate how it will get a financial close for the whole action. Independent experts will assess all deliverables and will advise for the go/no-go decision.

The selected projects are expected to contribute and participate to the activities of the project BRIDGE[48] when relevant

This R&I need is identified in the offshore renewable energy strategy (COM(2020) 741 final) that commits the Commission to 'develop new wind, ocean energy and solar floating technology designs, for example through Horizon Europe'.

Cross-Technology

D3-1-44. European Green Transition Signature Initiatives (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	To be decided
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Identification and creation of scale up pipelines based on ecosystem technology elements (research, infratechnology, prototypes, platforms).
- Efficiency gains via interservice and interprogram coordination and alignment.

Scope:

[48] https://www.h2020-bridge.eu/

- Renewables ecosystem as defined in the Annex to the Single Market Report and the upcoming Transition Pathway for the Renewables Ecosystem.

D3-1-45. European Green Transition Signature Initiatives (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	To be decided
Eligibility conditions	

Expected Outcome: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Identification and creation of scale up pipelines based on ecosystem technology elements (research, infratechnology, prototypes, platforms).
- Efficiency gains via interservice and interprogram coordination and alignment.

Scope:

- Renewables ecosystem as defined in the Annex to the Single Market Report and the upcoming Transition Pathway for the Renewables Ecosystem.

D3-1-46. Market Uptake Measures of renewable energy systems (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Coordination and Support Actions
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to some of the following expected outcomes:

- Facilitate the wider uptake of renewable energy systems in the energy, industrial and residential sectors leading to an increased share of renewable energy in the final energy consumption by 2030 and beyond.
- Contribute to provide a basis for policy-makers and stakeholders for developing more informed RES policy and for analysing about the market dynamics when including all renewable energies.
- Contribute to the development of markets and respective financial frameworks that can operate efficiently and incentive-compatible while accommodating massive shares of renewables.
- Increase societal acceptance of renewable energy facilities and installations through science-based evidence and tools addressing misperception phenomena from citizens.

Scope: The proposal is expected to develop solutions addressing at least 2 of the expected outcomes either for the entire renewable energy market or focusing on a specific energy sector, such as electricity, heating, cooling or renewable fuels. Proposals can also address issues within a specific geographical region such as urban and peri-urban areas. Issues related to acceptance of RES technologies due to cultural heritage landscape particularities can be addressed. Self-consumption issues can be addressed too. International aspects, such as collaboration with third countries and promoting solution in new markets, can be addressed as well.

The proposed solution can be developed to address a local challenge but needs to have wide potential for reapplication. The solution should have a long term viability and not be limited to an ad-hoc fix. The methodologies applied may be inspired by successful approaches already tested in other fields or contexts.

For all actions, the consortia have to involve and/or engage relevant stakeholders (e.g. businesses, public authorities, civil society organisations) and market actors who are committed to adopting/implementing the results. The complexity of these challenges and of the related market uptake barriers may call for multi-disciplinary approaches, which should include contributions from the social sciences and humanities. Where relevant, regional specificities, socio-economic, gender-related, spatial and environmental aspects will be considered from a life-cycle perspective.

Where relevant, proposals are expected to also assess the legal, institutional and political frameworks at local, national and European level and examine how, why and under what conditions these could act as a barrier or an enabler.

Cross Technology - International Cooperation

D3-1-47. Accelerating the green transition and energy access in Africa (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex B.
Eligibility conditions	The conditions are described in General Annex B. For the consortium, in addition to the standard eligibility conditions, at least two partners from at least one African country must be part of the consortium. For the criterion **'Quality and efficiency of the implementation'**, in addition to its standard sub-criteria , the following aspect shall constitute a major element: Proven access to necessary land and / or permits for operation at the time of application and / or convincing risk management regarding delayed availability of land or permits. Risk management can include go / no-go decisions at mid-term.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Technologically reliable and economically viable renewable energy solutions by 2030.

- Climate adaptation and climate mitigation potential of the solutions compared to other technologies/solutions.
- Strengthening of the joint EU-AU Climate Change and Sustainable Energy Partnership efforts, with emphasis on improving the visibility of EU Science Diplomacy actions in Africa.
- Proven positive environmental, health, climate, social and economic impacts of the renewable energy solutions.
- Acceleration of the achievements of the African continent's targets of the Paris Agreement.

Scope:

The proposal should demonstrate innovative sustainable energy solutions that consider climate adaptation and mitigation potential compared to other technologies/solutions in the African social, economic and environmental contexts. The proposal may address development of renewable energy sources, including solutions for off-grid communities, and their integration into the existing energy system, considering the generation of renewable energy, the transmission, and the use of storage/battery systems.

The action should cover either urbanised or rural contexts in Africa. It should help reducing the stress on the water-energy-food environment, with the aim of providing sustainable energy access and creating improved health, economic wealth and jobs.

Actions should design, construct, commission and operate the demonstration installation. Actions should also develop and implement a tailored value chain approach, identifying the most suitable manufacturing value chains, on the basis of the local context, local material supply chain(s) and local workforce, with the objective of ensuring sustainable local economic development. Actions should also include the identification of technical, vocational and educational needs of the workforce and propose relevant training and qualification activities. Actions should finally define a market and business strategy to ensure impact through a quick and viable commercial take-up of the technological solution demonstrated.

Proposals should include a life cycle analysis showing the impact of the proposed solutions compared to other technologies/solutions on the environment, on climate change targets and on the social and the economic dimensions, taking a cradle to grave viewpoint. Where relevant, proposals should consider adopting a circular economy approach,

As the demonstration installation will be located in Africa, relevant African partners have to participate in the implementation of the project. A balanced consortium between European and African partners will be considered an asset in the evaluation.

Actions should also participate in and contribute to the EU/AU Partnership on Climate Change and Sustainable Energy, in particular through cooperation/collaboration with the project LEAP-RE, “Long Term EU-Africa Partnership for Research and Innovation actions in the area of renewable energy”, www.leap-re.eu.

D3-1-48. Africa-EU CO-FUND action (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Co-fund (with 50% EC share)
Technology Readiness Level	N/A
Eligibility conditions	The conditions are described in General Annex B. Consortium: In addition to the standard eligibility criteria, at least 40% of the partners should be from Africa. Beneficiaries may provide financial support to third parties. Financial support provided by the participants to third parties is one of the primary activities of this action to allow the partnership to achieve its objectives. Therefore, the EUR 60 000 threshold provided for in Article 204 (a) of the Financial Regulation No 2018/1046 does not apply.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Strengthening of the joint EU-AU Climate Change and Sustainable Energy Partnership efforts, with emphasis on improving the visibility of EU Science Diplomacy actions in Africa.
- Acceleration of the achievements of the African continent’s targets of the Paris Agreement.
- Establishing technologies for an energy system that meets the needs of different parts of society, in different geographical locations (urban and rural) and different groups.

<u>Scope</u>:

Following the EU commitments under the Paris Agreement, Agenda 2030 on Sustainable Development and the Cotonou Agreement, the renewed objective to evolve current forms of cooperation into equal footing partnership between Africa and Europe, the current research and innovation cooperation between Europe and Africa in the field of renewable energy needs to be further strengthened and developed.

The action should contribute to the continuation of implementation of the strategic and joint research and innovation actions roadmap done under Pilar 1 of the project LEAP-RE, "Long Term EU-Africa Partnership for Research and Innovation actions in the area of renewable energy", www.leap-re.eu. The range of activities supported shall address the broad range elements identified in LEAP-RE and shall include a well-balanced set of research projects, demonstration projects, and technology transfer projects. Inclusiveness of a broad range of MSs/ACs and African partners will be considered an asset.

The proposal should envisage clustering activities with other relevant selected projects for cross-projects co-operation, consultations and joint activities on cross-cutting issues. To this end, proposals should provide for a dedicated work package and/or task, and earmark the appropriate resources accordingly. The partnership should also present and implement a joint programme of activities focussed on communication (participation in joint meetings and communication events), dissemination and exploitation.

It is expected that the action will organise joint calls on an annual basis and will consider ample time for the implementation of the co-funded projects.

The proposal should also provide support to the operation of the EU/AU Partnership on Climate Change and Sustainable Energy.

Breakthrough

D3-1-49. Next generation of renewable energy technologies

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology	Activities are expected to achieve TRL 3-4 by the end of the project –

Readiness Level	see General Annex B.
Eligibility conditions	The conditions are described in General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Available breakthrough and game changing renewable energy technologies enabling a faster transition to a net-zero greenhouse gas emissions EU economy by 2050.
- Knowledge and scientific proofs of the technological feasibility of the concept including the environmental, social and economic benefits to contribute to R&I strategy and policy forecast.
- Establishing a solid long term dependable European innovation base.

Scope: The proposal is expected to address high-risk/high return technology developments for game changing renewable energy technologies including catalyst development, dedicated storage systems and integration of renewable energy technologies into a single energy generation system, heating & cooling systems, fuels production systems, hybrid electricity generation solutions between different renewable energy sources, direct utilization of renewable energy sources.

The following areas should not be covered as they fall within the scope of partnerships or other calls:

- Hydrogen production through electrolysers;
- Fuel cells;
- Batteries as being covered in Destination 2.

The proposal should validate its concept to TRL 3 or TRL 4 through a robust research methodology and activities, establish the technological feasibility of its concept, consider transfer developments in sectors other than energy whenever relevant, as they may provide ideas, experiences, technology contributions, knowledge, new approaches, innovative materials and skills.

In developing its concept the proposal is expected to address the following related aspects: lower environmental impact, better resource efficiency (materials, geographical footprints, water, etc…) than current commercial renewable technologies, issues related to social acceptance or resistance to new energy technologies, related socioeconomic and livelihood issues. Considerations should be given to the regulatory frameworks for their adequate integration.

Energy systems, grids & storage

Energy Sector Integration

D3-2-1. Increasing the efficiency of innovative energy conversion technologies (electricity, heat, cold generation)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected outcome: Project results are expected to contribute to all the following expected outcomes:

- Increased potential for wider application for electricity generation as well as heat/cold generation due to increased efficiency of Thermoelectric Generators (TEGs).
- Optimised application of TEGs in heat recovery in industrial, automotive, solar, geothermal, data centres, buildings applications, etc.

Scope: A thermoelectric effect is a physical phenomenon consisting of the direct conversion of heat into electrical energy (Seebeck effect) or inversely from electrical current into heat (Peltier effect) without moving mechanical parts. TEGs are environmentally safe, work quietly as they do not include mechanical mechanisms or rotating elements such as turbines, which eliminates extra costs resulting from maintenance and replacement. TEGs can be manufactured on a broad variety of substrates such as silicon, polymers and ceramics. The low energy conversion efficiency, the need of a constant heat source and the high cost are the main disadvantages.

Projects are expected to implement and deliver on:

- Simulate, analysis, design, test and demonstration of innovative thermoelectric generators converting natural heat source energy directly into electricity (Seebeck effect) with applications in energy waste recovery (e.g., industry, geothermal, data centres, buildings, automotive, etc.) as well as others.
- Simulate, analysis, design, test and demonstration of innovative thermoelectric generators converting electricity directly into heat/cold energy (Peltier effect) with applications in cooling equipment (e.g., in industrial processes such as metallurgy, semiconductor lithography, etc., to cool or heat control elements, to cool Li-Ion-Batteries of electric cars, etc.) as well as others.
- The development of new efficient thermoelectric materials to overcome the drawbacks of their interconnected electrical and thermal properties.
- New designs of thermoelectric generators that allow better integration into energy conversion systems, from the point of view of efficiency and the environmental impact.
- Potential use of nanotechnology for the development of innovative TEGs.
- Cost benefit analysis for the use of TEGs compared to other traditional energy converters

D3-2-2. Integration of renewable gases other than hydrogen or methane and which have not access to gas grids and interfacing with electricity and heat sectors

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex B.

<u>**Expected outcome:**</u> Project results are expected to contribute to the following expected outcomes:

- Accelerate the integration of unrefined renewable gaseous fuels in the energy system.
- Increase flexibility, reliability and security of renewable energy supply in the energy sector.
- Increase integration of electricity and heat/cooling sectors with gas grids.
- Increase technology leadership, competitiveness and technology export potential of European hydropower industry.

Scope:

Demonstration of decentralized production of renewable gaseous energy carriers other than hydrogen and purified biomethane, namely biogas and syngas for example, and its integration in local energy systems for direct electricity and heat and cooling production. Demonstration of the integration of small and flexible modular gas production units, its associated infrastructure and development of digital interfaces for the connection to electricity and heat/cooling sectors are included. The integrated modules and components should be optimized to increase flexibility, security, affordability and robustness to the local energy supply. Conditions for injection to the grid of renewable unrefined gases should be identified. A techno-economic analysis should be included to address the cost-effectiveness of the integrated solution. A life Cycle Analysis should be carried out for the assessment of the GHG emission reduction due to the renewable gas integration. Effects of Community involvement shall be addressed with an analysis of socioeconomic sustainability.

Energy system planning and operation

D3-2-3. HVDC Operation: development and integration of advanced software tools in SCADA systems for AC/DC hybrid systems

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	7

Expected outcome: Project results are expected to contribute to all the following expected outcomes:

- Developed innovative algorithms and software tools for analysing and controlling the system of mixed, hybrid AC/DC grids.
- Integration of these tools into the control room software.
- Real-time capable algorithms and tools that enables optimal operation of the hybrid AC/DC system (e.g., avoidance of circular flows) and to support security analyses.
- Innovative ancillary services (e.g., frequency control, mitigation of periodic frequency fluctuations, voltage regulation and reactive power control).
- The possibilities offered by fast HVDC control in terms of islanding, black-start capability, firewalling shall be exploited for fault impact minimisation/avoidance.
- Increased security of supply through firewalling cascading effects due to faults or cyberattacks by segmentation of the grid with an HVDC link.
- Support for fault identification and return to safe, normal operation.

Scope: Projects are expected to implement and deliver on:

1. Development and demonstration of methodologies, algorithms and software tools for:

    - Scalable and flexible software framework for operation of hybrid AC/DC power systems supporting various vendor-dependent system and component models, e.g., more accurate and wider representation of connected systems, power flow calculations.
    - Upper-level Control of voltage source converters (multi-vendor, multi-terminal), including changing active power set points, voltage/reactive power control set points and changing controller parameters.
    - Robust online estimation and calculation of the system state of the AC, DC and hybrid system.
    - Control of the hybrid system considering system stability, optimal asset utilisation and market requirements.
    - Manage ancillary and balancing services across hybrid AC/DC grids.
    - Safety and reliability analysis of the system state, analysis of possible failure situations as well as curative measures for the failure event, e.g., transient and dynamic stability, coordinated risk management.
    - Calculation and determination of solutions for AC/DC system protection.

- AI-based decision support systems supporting technical and market aspects.
- Unified Human Machine Interface (HMI).
- Integration of cyber secure, resilient ICT platforms and communication for data exchange.
- Integration of standardised data protocols.
- Definition of required basic software tools features set to support operation for multi-vendor operation.
- Upgrade of power flow control tools and sophisticated optimisation techniques considering AC/DC systems.
- AI-based decision support systems.
- Vendor independent hybrid HVDC/AC network SCADA/Energy Management System.

2. Develop at least three pilots in different Member States/Associated Countries for fully automated decision support systems for control centres and to develop, test and validate the above methodologies, algorithms and software tools.

D3-2-4. AI Testing and Experimentation Facility (TEF) for the energy sector – bringing technology to the market

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Expected outcome: Project results are expected to contribute of the following expected outcomes:

- Large-scale reference testing and experimentation facilities (TEFs) will offer a combination of physical and virtual facilities, in which technology providers can get support to test their latest AI-based software and hardware technologies in real-world environments.

- This will include support for full integration, testing and experimentation of latest AI-based technologies to solve issues/improve solutions in the **energy sector**, including validation and demonstration.
- The TEF is open to all the sites in Europe and should be equipped with the right equipment (Infrastructure & latest AI).
- The TEF is a "long term investment". There should be a business model to guarantee self-sustainability.
- (TEFs can also support regulatory sandboxes by setting up a dialogue with competent national authorities for supervised testing and experimentation under real or close to real conditions).

Scope:

- The TEF is a technology infrastructure that has specific expertise and experience with testing in real conditions in the energy sector. They should build on existing infrastructures, facilities.
- TEF should become a common resources open to all the players, especially end users who should closely involved.
- The TEF has the scope to then bridge the gap between lab and market due to the lacking of in depth testing of AI technology in the real environment to fully validate them before the deployment.
- Energy AI TEF will aim at testing mature AI–based technologies and solutions that have already been tested in the labs, and have to be tested in real-world environments.
- Energy AI TEF shall give regions a further boost in attracting funding to upgrade its facilities and also attracting innovative players to collaborate with its own champions. In addition, TEF will contribute to more trustworthy AI made in Europe.
- TEFs seek to support technology providers, but we also expect TEFs to include end-users of the technologies to ensure co-creation (in particular end-users can be involved in defining testing scenarios, protocols and metrics, relevant to their sectors).

D3-2-5. System approach for grid planning and upgrade in support of a dominant electric mobility (vehicles and vessels) using AI tools

Specific conditions	
Expected EU	The Commission estimates that an EU contribution of XX million would

contribution per project	allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Expected outcome: Project results are expected to contribute of the following expected outcomes:

- AI-based prediction of most convenient locations that optimize grid resources and upgrades around recharging pools for EVs and electric HDVs.
- Developing of spatial mapping models and software tool for location decision-making with a comprehensive focus, including major highways, industrial zones (depot charging), urban nodes (e.g., for overnight charging) and less-densely populated areas.
- Simulation, analysis, design, test and demonstration of smart and bidirectional charging schemes and their integration into flexibility markets that allow to minimise the impact on grid planning and connection of high-power recharging pools for recharging EVs, and especially HDVs on more cost-intensive locations, and that ensure benefits to consumers based on smart charging energy service models.
- Exploration of the impact of different charging methods, including cable-charging, wireless charging and electric road systems covering either catenary as inductive coils embedded in the road.
- Analysis, design, testing and developing of a cyber security model that can simulate and accurately represent attack propagation from recharging infrastructure entry vectors, informing the development of efficient strategies and lines of defence to mitigate these vulnerabilities for the different relevant stakeholders.

Scope:

The activities shall include, at least the following aspects:

- Definition and development of new AI-based tools to predict, estimate and plan the deployment and associated challenge for utilities (from an EV recharging ecosystem viewpoint - CPO, DSO and TSO) on how to deal with the increasing upcoming demand in numerous new locations, particularly during peak periods.
- Understanding on how to effectively deploy the required grid connection (and power) in less densely populated areas, exploring the impact of installation of batteries to expand the grid in combination with renewables.

- Development of a coherent energy system planning for electric mobility, considering both the needs and impact for recharging of EVs and onshore power supply of vessels in maritime ports and inland waterways.

- Development of new services for consumers (EV and HDV owners, leasers, etc.) based on smart charging that valorise the flexibility in the wholesale, home optimisation and/or grid services markets. Integration of smart charging services with flexibility from other devices (e.g. demand response) would be an added value for the project.

- There is an increasing risk for the occurrence of a scenario where EVs and/or recharging stations could be hacked simultaneously, causing a disruption to grid operations, propagating rapidly with dire consequences, such as blackouts and overall affection of the frequency stability of the grid. The project should bridge the gap between recharging infrastructure operators, EVs and the grid (DSOs, TSOs), identify existing weaknesses and risks for attack spread.

- The developed solutions should assess their environmental impact in particular with regards to their energy consumption.

The selected project is expected to contribute to relevant BRIDGE[49] activities.

Active consumers, Markets and Energy Communities

D3-2-6. Digital tools for enhancing the uptake of digital services in the energy market

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Expected outcome: Project results are expected to contribute to all of the following outcomes:

- Development and uptake of innovative data-driven cross-sector integrated services, solutions and products using cross-sectorial data resulted from other sectors than energy (e.g. data economy, health, finance, security) that empower consumers and

[49] https://www.h2020-bridge.eu/

facilitate consumer investment in the energy transition (e.g. renewables, energy efficiency, renovation, demand response, storage).

- Development and fast market-uptake of digital twin models of household energy consumers to help consumers, citizens, energy suppliers, aggregators and energy communities to optimise data-driven energy (and other sector) services and to enhance digital energy literacy;
- Greater access for consumers to the wide range of emerging services and applications that will be present in the market resulting from data sharing and benefiting from increased interoperability;
- increased simplification of management and improvement of quality of new and current energy services and new digital platforms, smart meters and tools to provide consumers with seamless omni-channel experiences;
- Creation of value and direct benefit for the consumers and support digital empowerment and energy literacy of citizens: European citizens are educated, motivated and empowered to use digital tools to be an active participant in the energy transition.

Scope:

Digitalisation develops faster than the ability of society to adjust. Digital technologies are a driving force for empowering citizens in taking on an active role in the energy transition. Increased acceptance of new digital technologies is pivotal: actions should focus on benefits of new digital services and users experience to overcome the expected friction of end-consumer on boarding, developing innovative tools for engagement and literacy. Social innovation tools and multi-disciplinary approaches and engagement of policymakers at various levels, the private sector, civil society and citizens at large are required.

Accordingly, proposed activities will address all of the following:

- Use the data provided by real time sensors and real time computing resulting from other sectors than energy (e.g. data economy, health, finance, security) to generate new businesses and new ways of benefiting the economy and society by developing of innovative data-driven cross-sector integrated services, solutions and products.
- Help consumers and citizens navigate the new digital technologies entering the energy market, taking into consideration the cross sectorial dimension alongside the sector-specific one, also exploring the possibility of using AI-based assistant tools.
- Trigger and support the development of a digital tool allowing citizens to visualise and access to all the energy-related data they produce and share with third parties, thus helping to exert their right to understand and control their data.

- Test the developed cross-sector services in at least 3 countries. In the selection of pilots, gender, demographic, geographic and socio-economic aspects should be duly taken into account.
- Develop and test, in at least 3 countries, a digital twin of the (household) energy consumer, making use of AI to assist the consumer (both in terms of optimising the service as well as enhancing digital energy literacy and enhancing understanding and trust of the AI used).
- The digital twin solutions shall be developed and made available as Open Source solutions, while making sure that contributors are recognised and fairly compensated, respecting well defined rules and within a network of trusted data, which guarantees security and sovereignty of data and services. in an Open Source way so that the developed software is available.
- contribute to the communication, outreach and dissemination strategy of the Communication on Digitalisation of the Energy System.

Projects are required to utilize the data exchange infrastructure that is being developed under ongoing EU-funded under Horizon 2020, Horizon Europe and the Digital Europe Program.

The project is required take into account, and collaborate with, where considered necessary, existing Living Labs (e.g. EnergyVille, TomorrowLab and living labs funded entirely by EU projects as study or demonstration site) to test integrated consumer services the ongoing relevant Blueprint projects from the Erasmus + program, relevant initiatives by Digital Innovation Hubs, the European Climate Pact, EC Digital Education action plan and any other relevant initiative.

Projects are required to seek synergies with Horizon Europe instruments, including those of bottom-up nature like ERC, MSCA, EIT KICs, as well as its European partnerships.

Moreover, projects are expected to participate in all relevant BRIDGE[50] activities and to take into account the outcomes of the work of the Citizens and Consumers Engagement Working Group and data coming from the Consumers Empowerment Benchmark developed by the European Commission.

D3-2-7. Creation of an open-source block-chain based default Peer-to-peer platform

Specific conditions[51]	
Expected EU	The Commission estimates that an EU contribution of XX million

[50] https://www.h2020-bridge.eu/

[51] These are the absolute minimum conditions. Additional conditions may be added as needed (see section 1).

contribution per project	would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	*TRL 6-8*

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Develop an independent, EU-validated flexibility and peer-to-peer trading solution for consumers willing to engage in such operations.
- The project should set rules for using the tool.
- Such an alternative shall be open source, freely accessible.
- Increased consumer engagement and acceptance.

Scope:

The activities include, but are not limited to:

- Defining the core operations for a flexibility and peer-to-peer trading platform should execute in order to:
  - Guarantee optimal valorization and integration of DER;
  - Take into account network constraints;
  - Meet the local consumers' needs and characteristics.
- Developing an AI-based software that use machine learning processes to integrate core operations and local grid constraints in order to adapt to variations and changes in grid conditions.
- Testing cases for blockchain-based trading operations following an agile methodology with the objective to get a fully functional trading tool within the project lifetime.
- Developing field studies in LECs to integrate bottom up approaches.

- Involve energy cooperatives or local/renewable energy communities *[include reference to the articles in the Electricity and Renewable Directives]* in each selected project.

The developed solutions shall be freely available to citizens, energy cooperatives and local/renewable energy communities *[include reference to the articles in the Electricity and Renewable Directives]*.

Solutions shall be developed and made available as Open Source solutions, while making sure that contributors are recognised and fairly compensated, respecting well defined rules and within a network of trusted data, which guarantees security and sovereignty of data and services.

The selected projects will cooperate among themselves and with other relevant projects through regular common workshops, exchange of non-confidential reports, etc.

Selected projects are expected to contribute to relevant BRIDGE[52] activities, especially with projects that are testing peer-to-peer feasibility in real conditions

TSO/DSO Flexibility Management

D3-2-8. Supporting the development of a digital twin to improve management and operations in the EU Electricity System

Specific conditions[53]	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	e.g. IA TRL 6-7

<u>Expected outcome:</u>

[52] https://www.h2020-bridge.eu/

[53] These are the absolute minimum conditions. Additional conditions may be added as needed (see section 1).

The projects implementing a Digital Twin to improve management and operations of the EU Electricity System to increase the share of renewables in an efficient way should aim at the following expected outcomes:

- Promote new ways for energy companies, in particular between TSOs and DSOs, and between TSOs and DSOs on the one hand and market parties on the other hand, to share data and break the data-silos (simplify the data maintenance and exchange process).
- Synchronize data from various systems then standardize it into one multi-user centralised or distributed platform via standards-based adapters or interfaces, compliant with and integrated with the Common European Energy Data Space.
- Investigate how the electricity grid responds to stimuli or shocks (e.g. RES integration, cyber-attacks).
- Test and pilot the applications of science and innovation [e.g. combination of key digital technologies] in the energy sector [e.g. testing the combination of HPC, Big Data, AI, IoT and Cloud Computing] in order to foster the rapid development of Digital Twins and new services based on them (e.g. real time and interactive computing)]

Scope:

The scope of this project is thus twofold:

Firstly, it aims at strengthening data sharing between networks operators on the operation and functioning of the grid through the joint development of a Digital twin, in order to enable an optimized management of the grid, and it aims at strengthening data sharing between TSOs and DSOs on the one hand and market parties on the other hand.

Secondly, it should also aim at supporting relevant stakeholders to develop innovative solutions based on this Digital Twin (e.g. RES Signal etc...) that can benefit other actors, e.g. Cities.

The resulting digital twin of the grid should be modular, cover both the high-voltage and digital parts and be implementable at different scales, achieving different aims, including at local level and distribution grid optimisation, integrating both (decentralised) supply and demand-side, taking into account energy data coming from buildings, local storage, DER, electrical vehicles, etc. It should also be interoperable with other digital twins (e.g. buildings/cities/communities twins). To ensure interoperability and integration into the grid and the federated European digital infrastructure, specific demonstrators will make use of operational end-to-end architectures, digital platforms and other data exchange infrastructure for the energy and cross-sector systems being developed under ongoing Horizon 2020, Horizon Europe as well as under other EU programs such as the Digital Europe Program and Connecting Europe Facility.

The selected projects are expected to contribute to relevant BRIDGE[54], AIOTI and other relevant (e.g. clusters of digital projects and coordinating actions) activities.

D3-2-9. Energy Management Systems for flexibility services

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
	TRL 7-8

Expected outcome: Project results are expected to contribute to [all/at least XX] of the following expected outcomes:

- Contribute to the use of smart buildings and smart industrial sites for the integration of renewables in the energy system in an efficient way;
- Demonstrate aggregation of multiple (building or industrial) energy management systems to provide flexibility services (wholesale market price signals, demand response, flexible production, smart charging, balancing, congestion management) to the electricity network;
- Demonstrate interoperability and data exchange technologies to aggregate data from different sources and in different formats through cooperation between aggregators and energy management system developers.

Scope:

Projects are expected to:

- Develop solutions to aggregate flexibility from different (types of) energy consumers that use different energy management systems to develop interoperable solutions to

[54] https://www.h2020-bridge.eu/

optimise the energy management systems and valorise its flexibility in wholesale markets and for balancing and/or congestion management services).

- Cooperate with (one or more) TSOs and/or DSOs, preferably making use of day-to-day operational flexibility markets (i.e. not R&I projects or regulatory sandboxes).
- Include at least 3 different energy management systems in case of industry, or 5 in case of buildings, developed by different technology providers and that use different protocols/standards/proprietary solutions for the energy management system.
- Involve at least 3 different energy system management service companies in in case of industry, or 5 in case of buildings.
- Include at least 2 aggregators to ensure that developed solutions are based on standards and to avoid proprietary solutions.
- To ensure interoperability and integration into the grid, specific demonstrators will make use of operational end-to-end architectures, digital platforms and other data exchange infrastructure for the energy system being developed under ongoing Horizon 2020, Horizon Europe as well as under other EU programs such as the Digital Europe Program.

The selected projects are expected to contribute to relevant BRIDGE[55] activities.

Electricity system reliability and resilience - grid architecture

D3-2-10. DC and AC/DC hybrid transmission and distribution architecture and systems

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	7-8

[55] https://www.h2020-bridge.eu/

Expected outcome: Project results are expected to contribute to all the following expected outcomes:

a. Demonstrated top-down electricity system orchestration of future pan-European AC / DC hybrid system architecture at different voltage levels (HVDC, MVDC. LVDC) down to DC microgrids (TRL 6).

b. Demonstrated grid forming technologies to be applied to the energy system to address the gradual loss of inertia caused by the increasing penetration of Power Electronics Interfaced Generators (= RES such as PV, Wind, etc.) (TRL 6).

c. Demonstrated DC distribution systems and technologies (TRL6).

Scope:

Projects are expected to implement and deliver on:

1. R&I activities, methodologies and tools:

   a. DC – AC / DC hybrid system Design & Planning

   - Demonstration of software tools for transnational AC/DC hybrid power system planning and management to enable HVAC/HVDC/MVDC/LVDC hybrid systems, such as: a) integration of multi-terminal HVDC systems, both offshore and onshore and HVDC links embedded within the HVAC network as well as HVDC ties (inter-)connecting different control zones and synchronous areas (in full or in back-to-back schemes); b) representation and modelling of distribution grids as well as multi-energy vector integration (sector coupling) for long-term analysis.
   - Demonstration of reliability and resilience methodologies to address security and adequacy issues and criteria via not only deterministic but also probabilistic (e.g., Monte-Carlo) methods.

   b. Grid Forming Capability

   - Functional requirements and demonstration of grid forming capability at the onshore system interface of the high voltage transmission (grid connection point of the onshore HVDC converter station) of an HVDC system connecting offshore wind power parks.
   - Functional requirements and demonstration of grid forming capability at both the sending and the receiving converter station of an embedded HVDC transmission system.
   - Functional requirements and demonstration of grid forming capability at the onshore grid connection point of an HVDC converter station being part of a multi-terminal HVDC grid.

- Functional requirements and validation procedure for testing grid forming capabilities offered by HVDC systems (embedded or connecting offshore wind power parks in point to point or multi-terminal connection) by means of simulation models.

c. DC Distribution & microgrids

- Modelling (steady state and transient models) for systems including different typology of RES, EVs, storage and loads (system architecture, voltage level, control, stability, protection, and storage integration).
- Planning and design of DC distribution grids as the intermediate layer between the HVDC and the Low Voltage local distribution grid and loads.
- Functional requirements for the DC/DC converters based on the different typologies and power rating applications.

2. Develop at least 3 pilots in different Member States/Associated Countries to develop, test and validate the above R&I activities, methodologies and software tools.

D3-2-11. Demonstration of DC powered data centre, buildings, industry and ports

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	8

Expected outcome: Project results are expected to contribute to all the following expected outcomes:

- Demonstrated benefits and efficiency of DC power distribution systems compared to AC (no need of AC/DC conversion, less copper, less space occupancy, etc.).

Scope:

Projects are expected to implement and deliver on:

1. R&I activities, methodologies and tools:

   DC powered data centre:

   - Design and demonstration of a DC powered data centre;
   - CBA of the savings compared with the standard AC powered data centre.

   Application of DC distribution in commercial and residential buildings

     - Installation of intelligent DC system complete of all the related components (e.g., RES, DC bus, sockets, LED lighting, heat pumps, EV charging stations, storage systems, etc. The components can be either DC-based or AC-based and appropriately adapted to work within the DC grid.
     - Identification of the efficiency of a DC system compared to an AC system in the building sector and the corresponding cost savings.
     - Analysis and identification of the main barriers (technical and non-technical) for the development and deployment of LVDC systems.

   Application of DC distribution in industry

     - Development and demonstration of DC manufacturing process installation, protection and device technologies.
     - Development of project management tools and methods.
     - Demonstration of increased energy efficiency measures such as, for example the use of variable-speed motors, led lighting, storage systems, etc.
     - Investigations to enable selectivity between circuit protection devices using different technologies, such as semiconductor breakers, hybrid semiconductor breakers, mechanical breakers and fuses.
     - Systems grounding to avoid stray currents and corrosion phenomenon from DC systems such as e.g., rail applications.
     - Insulation materials and their applicability for DC loads (investigation on suitability of AC cables for DC, on polarisation effects leading to early degradation and subsequent insulation failure, etc.).

   Application of DC distribution in ports

   - Simulation, analysis, design, develop, test and demonstration of a DC port infrastructure.

- Study and development of a tool to estimate the quantity of DC charging infrastructure necessary to support regional adoption of ports' electrification by MS.

- CBA at system level of a DC compared to an AC supplied port considering all the elements contributing to a real effective analysis on the costs and benefits of the system.

- Simulate, analysis, design, test and demonstration of all the IT needed for the grid automation.

- Analysis and definition of possible operating framework and business models for ports acting as energy hubs.

Analysis, report and recommendations on the potential of the ports as energy hubs with related planning for its development within the energy transition.

2. Develop at least 3 pilots in different Member States/Associated Countries to develop, test and validate the above R&I activities, methodologies and software tools.

D3-2-12. Support action to the SET-PLAN WG on HVDC

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	CSA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Smooth implementation through supporting actions of the Plan for HVDC in the coming years for the offshore as well as onshore grid development.

Scope:

- Organisational support to the Implementation Working Group on HVDC.

- Organisational support for workshops, conferences, etc.

- Documents and files management.

Electricity system reliability and resilience - risk preparedness

D3-2-13. HVDC control and protection: Components and interfacing for AC & DC side protection system – AC grid: components and systems for grid optimisation

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	7

Expected outcome: Project results are expected to contribute to all the following expected outcomes:

HVDC:

- AC & DC side protection strategies and readiness of their functional design, to support grid optimal architecture planning and prepare project tendering.
- Methodology to assess admissible temporary loss of transmitted power in case of DC fault.
- Multi-vendor interoperable HVDC grid protection.
- HVDC grid protection strategies and design.
- AC & DC side protection system functional design for fully selective and partially selective fault clearing strategies, including the connection to low-inertia AC systems.

AC:

- Innovative Power Electronics-based technologies properly placed in the grid address congestion due to the injection of decentralised energy in a centralised-based electricity system.

- Optimisation of the power flows by shifting power transfer from loaded to unloaded lines.

Scope: Projects are expected to implement and deliver on:

1. R&I, methodologies and tools for

   HVDC:

   - Methodology to assess admissible temporary loss of transmitted power in case of DC fault
     - AC-DC transient stability, when DC transmitted power is temporarily and partially interrupted, in case of a DC fault.
     - Impact of reactive power supply transient interruption (converter blocking).
     - In case of HVDC-connected Off-Shore Wind farm: coordination of control actions from HVDC and wind turbines o Anticipation of new system dynamics due to high PEID penetration.
     - Impacts of partially selective versus fully selective DC fault-clearing strategies.
     - Impacts mitigation.
     - Recommendation for AC-DC system design and DC protection design.
   - Multi-vendor interoperable HVDC grid protection
     - Improved methodologies for the determination of functional requirements of DC grid protection in a technical and vendor neutral manner.
     - Standardised validation tests for de-risking interoperability issues.
     - Specification of protection component and auxiliary ratings.
     - DC substation Communication architecture and protocols (e.g., IEC 61850 for DC).
     - Protection system simulation models and information exchange.
   - HVDC grid protection strategies and design
     - Methodologies for the protection of mixed (OHL/cable, bipolar/monopolar) DC grids.
     - Methodologies to optimally determine the optimal HVDC grid protection system, including combined selective, non-selective and partially protection schemes within the same DC grid.

    - Development of converter assisted HVDC grid protection.
    - DC station design and optimization from protection point of view.
  - AC & DC side protection system functional design for fully selective and partially selective fault clearing strategies, including the connection to low inertia AC systems
    - Protection functions;
    - Mains, back-ups;
    - KPIs.

AC:

  - Simulate, analysis, design, develop, test and demonstration of advanced Power Electronics-based equipment inserted appropriately in specific points in the grid to decongestion the lines.

Cost Benefit Analysis compared to other solutions (e.g., the use of DC systems, etc.) at system level and covering the operating life of the equipment.

2. Develop at least 3 pilots in different Member States/Associated Countries to develop, test and validate the above R&I activities, methodologies and software tools.

D3-2-14. Condition & Health Monitoring in Power Electronics (PE) - Wide Band Gap PE for the energy sector

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Technology Readiness Level	6-8

Expected outcome: Project results are expected to contribute to all the following expected outcomes:

C&HM

- Capability to anticipate failures of Power Electronics (PE) in wind farms and converters of the DC grid to prevent downtime.
- Techniques to set the equipment in limp mode to enable to withstand the stress until next maintenance.
- Demonstration of Condition and Health Monitoring (C&HM) for converters of wind turbines generators and HVDC converter stations

WBG PE

- Availability of more efficient Power Electronics components for the development of new generation of inverters, converters and other power equipment in the energy sector.
- Reduced space occupancy aiming mainly at offshore applications.
- Improved cost efficiency of power devices and semiconductor fabrication processes.

Scope: Projects are expected to implement and deliver on:

1. R&I, methodologies and tools for

   Condition and Health Monitoring (C&HM):

   - Estimation of junction temperature Tj based on TSEPs (thermo-sensitive electrical parameters). Here especially big challenge present SiC MOSFETS and Schottky diodes because the TSEPs sensitivity is lower, non-linear and depends on the built technology. Further issues are calibration, circuit drift, influence of PWM and other.
   - Development of new and evaluation/further development of already existing unconventional techniques to measure temperature and estimate degradation (such as for example, but not limited to, Kelvin connection or acoustic based methods).
   - Development and evaluation of new or already existing techniques for generating the lifetime models based on big-data analysis and by utilisation of soft computing techniques.
   - Combination of (big) data-driven and physics-of-failure driven approaches in C&HM.

   Stress Steering:

- Successful business case realisation requires co-operation and communication between different partners:
    - manufacturers of power electronics components (for example to integrate sometimes necessary sensors).
    - system designer (to provide access to the data such as measured load cycles and general mission profiles).

companies responsible for operation and maintenance of the systems. Currently those companies are especially for offshore wind parks developing their own C&HM systems, which are operating, based on sometimes-scarce available data.

- Optimisation is possible when already initial products would be designed to obtain data/measurements needed in C&HM. For power electronics modules, the most valuable data seems to be Tj (junction temperature):
    - Careful estimation of the costs of maintenance for specified applications (it seems they are currently underestimated).
    - Investigation of different costs models (e.g., the final costs for C&HM can be absorbed by the producers especially when it is also responsible for maintenance or it can be transferred to the final user whenever the final user can provide safer and more reliable service).

<u>Wide Band Gap PE</u>

Improvement of wide bandgap semiconductors for integration in HVDC components. Work should focus on improving wide bandgap semiconductor devices, packaging and their integration in converter submodules:

- Improved WBG power devices with better performance metrics, e.g., lower conduction losses, higher blocking voltage, better surge current capability, higher switching frequencies, better short-circuit capability.
- Advanced control circuits for WBG based bridges.
- Improved packages featuring high-voltage insulation, high temperature operation, robustness, and low eddy currents.
- New submodule topologies for HVDC converters with WBG semiconductors and better performance metrics, e.g., reduced losses, higher reliability, lower volume / weight, less costs.
- Implementing WBG semiconductor devices for DC protection devices, e.g., DC breakers.

2. Develop at least 3 pilots in different Member States/Associated Countries to develop, test and validate the above R&I activities, methodologies and software tools.

Pan-European Transmission of Energy

D3-2-15. HVDC Technologies: Development of converter and HVDC systems and components for a resilient grid

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	8

Expected outcome: Project results are expected to contribute to all the following outcomes:

- Investigation and development of new converter systems (including back-to-back, floating, etc.) for higher efficiencies.
- Investigation and development of additional energy storage solutions, interfacing with HVDC systems, to support the AC system.
- Investigation and development of DC breaker integrated in Multi-terminal DC (MTDC) systems. DC breakers may be required when multi-terminal DC grid is materialised, to limit the loss of infeed caused by single point of failures.
- Investigation and development of the application of DC GIS in VSC HVDC converters, including economic benefits on overall system solution.

Scope: Projects are expected to implement and deliver on:

1. R&I, methodologies and tools for:

   - Development of smaller and more compact converter topologies that can result in significant cost savings offshore.
   - Carry out a technical analysis of possible trade-offs in performance, ambient condition impact, maintenance, reliability, dimensioning, testing procedures, etc.

- Demonstration of enhancement of AC system stability and AC system frequency by providing energy storage systems interfaced to HVDC systems.
- Assessment of technical and economic feasibility of application of DC breakers in MTDC systems.
- Demonstration of DC fault ride through capabilities in MTDC systems by using DC breakers.
- Assessment of potential new converter topologies addressing future offshore developments with the aim of reducing the CAPEX and OPEX of the investments, and with increased fault current capabilities.
- Boost SF6-free technologies in high-voltage equipment, as well as a regulatory roadmap for replacement and new assets:
    - Investigation and development of switchgears using air or natural gases with low impact on GWP. Alternative SF6 gases while at the same time ensuring low space occupancy for offshore applications on platforms. Environmental impact of alternative gases to be assessed.
    - Assessment of the economic and environmental impact of replacement and new installation rollout options (timeline, perspective of global market, full lifecycle impact).
    - Regulatory recommendations at EU level to cope with financial risks inherent with putting novel technologies into the system and transition time options to move from SF6 to SF6-free technology for new equipment.
    - Actual demonstrator for an SF6-free gas-insulated substation or for air-insulated SF6-free instrument transformers or switchgear at different voltage levels.

2. Develop at least 3 pilots in different Member States/Associated Countries to develop, test and validate the above R&I activities, methodologies and software tools.

D3-2-16. HVDC technologies: Cable systems

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	7

Expected outcome: Project results are expected to contribute to all the following expected outcomes:

[To be added]

Scope: Projects are expected to implement and deliver on:

1. R&I, methodologies and tools for:

   A. Higher voltage & current ratings

   - Optimisation of newly developed high electrical resistivity insulating materials for use above 525 kV.
   - Develop and pilot new network components with reduced environmental impact such as EHV/HV cables without lead, application of superconductors, DC cables/gas insulated lines for voltages above 550 kV.
   - Development of larger conductor cross sections.
   - Increase of maximum insulation operating temperature.
   - Further improving different types of extruded insulation materials (e.g., DC-XLPE, Polypropylene) cables, by refining the procedure of separation of the many components of the cable – insulation, wires, tapes, sheaths, etc. – from each other and their recycling procedure separation of the many components of the cable – insulation, wires, tapes, sheaths, etc. – from each other and their recycling procedure.
   - Feasibility study for use superconducting cables for submarine connections since they do not emit any heat.

   B. Predictive models for cable system ageing (fraction-of-life lost, remaining life), life and reliability

   - Modelling of space charge phenomena in newly developed insulating materials and its effects of cable system aging.

- Modelling of space charge phenomena in full size cables and its effects of cable system aging.

C. Monitoring and fault location systems

- Continuous temperature and acoustic monitoring of long cable system lengths.
- Accurate and instantaneous fault location systems for long cable system lengths.
- Further development and improvement of on-and off-line diagnostics and condition monitoring techniques for HVDC cable systems such as PD and leakage current measurements for online and space charge and dielectric permittivity and loss factor measurements for offline.
- Improved by incorporating innovative technological solutions such as robotic technologies for data collection and maintenance in in all type of location (easy-to-access and inhospitable).
- Develop procedures for optimised maintenance and repair concepts of offshore stations using BIM and 3D-Models.

D. Eco-designed and manufactured cable systems:

  - o SF6 free cable systems.
  - o Low carbon footprint insulation materials.
  - o Recyclability of cable materials.

E. Investigation and development of potential HVAC overhead lines replacement with HVDC to increase capacity transfer without the need of building new lines but reusing existing right of ways.

  - o Mapping of the potential use cases for replacement of HVAC with HVDC overhead lines supported by CBA.
  - o Conversion techniques for conversion of HVAC to HVDC with CBA.

2. Develop at least 3 pilots in different Member States/Associated Countries to develop, test and validate the above R&I activities, methodologies and software tools.

Storage development and integration

D3-2-17. Development of novel long-term electricity storage technologies

Specific conditions

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Activities are expected to achieve TRL 4-5 by the end of the project.

Expected outcome: Project results are expected to contribute to all the following expected outcomes:

- Increased availability, robustness and safety of sustainable and efficient energy storage solutions to reduce energy losses, increase cost effectiveness and improve the environmental footprint of the energy system.
- Availability and functionality of innovative energy storage systems developed for specific system designs and applications.
- Increase technology leadership, competitiveness and technology export potential of European storage technology industry.
- Enhanced sustainability of storage technologies, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities.

Scope:

Description: Development of novel storage technologies, which are providing best-fit in form of CAPEX, OPEX, efficiency and sustainability and are adapted to specific needs of the energy system. Examples for such specific needs are responsiveness to energy system flexibility need, necessary storage amount or specific requirements due to off-grid situations. Focus is on longer-duration technologies, compared to lithium-ion technology, which is currently dominating new storage projects. In scope are novel chemical, mechanical, thermic storage solutions, excluding batteries and hydrogen. Innovative storage solutions should show clear innovation with respect to the state of the art e.g. through use of new advanced materials or new design solutions, always bearing in mind the objective of sustainability and circular economy, minimizing the environmental footprint. The developed solutions shall be highly performant in respect of expected future investment and operational costs and business cases in existing or emerging energy markets and go beyond the state-of-the art of existing storage solutions in respect of sustainability, technical performance, including round-trip efficiency, lifetime, non-dependency on location geographical particularities strategic independence (=no or limited use of CRMs) and cost. Underlying basic material research is excluded.

D3-2-18. Demonstration of innovative seasonal heat and/or cooling storage technologies

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Activities are expected to achieve TRL 7-8 by the end of the project.

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Increased availability, robustness and safety of sustainable and efficient choices for energy storage to reduce energy losses, cost effectiveness and improve the environmental footprint of the energy system.
- Availability and functionality of innovative energy storage systems developed for specific system designs and applications.
- Increase technology leadership, competitiveness and technology export potential of European storage technology industry.
- Enhanced sustainability of storage technologies, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities.

Scope:

Demonstration of innovative heat and/or cooling storage technologies, which address long-term energy storage up to cross-seasonal storage. Solutions shall be embedded into District-level heating and/or cooling storage and optimise CAPEX, OPEX and process efficiency of heat storage, as well as circularity and sustainability of the system and its components, which shall be non-toxic, highly durable and reasonably easy to recycle. Strategic independence is to be considered, i.e. use of abundant materials whenever it is possible.

Basic material research is excluded.

D3-2-19. Demonstration of innovative pumped storage equipment and tools in combination with innovative storage management systems

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Activities are expected to achieve TRL 7-8 by the end of the project.

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Increased availability of innovative hydropower storage, in combination with innovative storage management systems.
- Maintain and increase technology leadership, competitiveness and technology export potential of European hydropower storage technology industry.
- Enhanced sustainability of hydropower storage technologies, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities.
- Reduced cost and improved efficiency of hydropower storage installations.

Scope:

Demonstration of innovative pumped storage equipment and digital tools linking the mechanical storage with innovative storage management systems. The latter may involve hybridisation with storage technologies to reap the full potential of pumped hydro storage under new market conditions Solutions shall deliver innovative hydropower technologies adapted to unconventional storage schemes, including e.g. low-head locations or former coal mines and/or harsher operation conditions, e.g. using salt water, while minimising CAPEX, OPEX and improving life time and circularity of components. For the storage management system, digital tools for strategic and operational management shall address current developments for energy storage, considering markets, variable renewable production and effects of climate change, and including novel approaches to energy. Demonstrated storage solutions shall respond to the highest standards of environmental sustainability and involve

Citizens and Communities, respectively. An analysis of innovative storage potential and impact shall be performed.

D3-2-20. Waste heat reutilisation from data centres

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Make seasonal storage solutions available to data centers to allow year-round optimised operation in urban environments in an integrated way to supply heat to neighboring district heating system(s), optimising use of excess heating energy and required cooling energy.

Scope:

Combining waste heat reuse with heat storage would allow data centres to relocate in more temperate area and better valorise their waste heat in winter (under the form of residential heating for instance) while storing this heat during hotter periods. From an economic perspective, the increase of waste heat that can be valorised and sold by the data centre during the appropriate seasons may compensate the additional costs of cooling during summer months (compared to installing data centres in much cooler regions in the extreme north of Europe).

Selected projects will test and further develop seasonal heat storage technologies through an integrated pilot that includes at least the following technologies:

- Heating and cooling exchange system for the data center and the district heating system;
- Seasonal energy storage.

Green digitalisation of the energy system - Interoperability and data

D3-2-21. Accelerating the development and piloting of AI-IoT Edge-cloud and platform solutions for the energy ecosystem to support its green and digital transformation and enhance its resilience

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

<u>Expected outcome:</u> Project results are expected to contribute to the following expected outcomes:

- Validation in a large-scale environment of the application of cutting-edge digital technology (Cloud-Edge continuum, edge intelligence, AI/ML, IoT) in a more decentralised environment in the energy sector.
- Fast spreading and market uptake of platform and cloud technologies for data exchange and storage to support innovative services (for flexibility, RES integration, etc.), across the EU, based on Open Source developed solutions, that enables further innovation in data-driven energy services by 3rd parties.
- Full set of digital standards applicable to the energy sector through extension and update of existing standards and new standards filling standardisation gaps.
- Application of highly distributed open platforms (operating systems) for distributed cloud-edge solutions in the energy area.
- Population of the Common European Energy Data Space with new high–value data sets.
- European Ecosystem in the Digitalisation of Energy area.
- Contribution to the implementation of the Digitalisation of Energy Action plan.

<u>Scope:</u>

- The action should develop and pilot on a large-scale cloud-edge solutions (including but not limited to bi-directional EV charging and smart buildings and homes) in a more decentralised environment for grid flexibility and energy services, based on digital enablers such as artificial intelligence, swarm computing and IoT.

- The solutions should be based to the greatest extent possible on the common European cloud-edge infrastructure. Any deviation should be duly explained and justified.
- There should be at least 5 pilot sites in at least 4 member states and an open call for additional services using up to 20% but not less than 10% of the total budget.
- The appropriate level of data localisation and processing (cloud, edge, far edge, etc.) should be defined on-the-fly by AI algorithms to optimise latency, energy consumption, security, and other important parameters.
- The developed solutions should aim to increase the integration of renewable energy sources, as well as the local generation and consumption of energy and processing of data.
- The solutions should be interoperable among themselves and with other European IoT research and innovation efforts in the energy and other sectors.
- The solutions should be based on commonly agreed open standards.
- To ensure interoperability and integration into the grid, the project will make use of operational end-to-end architectures, digital platforms and other data exchange infrastructure for the energy system being developed under ongoing Horizon 2020, Horizon Europe as well as under other EU programs such as the Digital Europe Program and Connecting Europe Facility, in particular Bridge, the Data Space design principles of Open DEI, the project supported under the Interoperability Community CSA and aligned with the Digital Europe Data Centre Support Centre;
- The selected projects are expected to contribute to relevant BRIDGE (*Home - Bridge (h2020-bridge.eu)*, AIOTI and other relevant activities.'
- The projects will be expected to contribute to the piloting, uptake and further development of relevant standards.
- The developed solutions should be easily upgradeable for long-term interoperability thus prolonging the life of IoT devices and decreasing the environmental footprint of the manufacturing and disposal.
- The developed solutions should assess their environmental impact in particular with regards to their energy consumption.
- The platform and cloud solutions developed shall be developed and made available as Open Source solutions, while making sure that contributors are recognised and fairly compensated, respecting well defined rules and within a network of trusted data, which guarantees security and sovereignty of data and services.

- Solutions should include a credible market uptake plan of developed solutions across the EU, in as diverse types of regions and electricity grids (in terms of climate, size, economic activities) and enable 3rd parties, in particular SMEs, to use the developed solutions as a basis to build their innovative data-driven energy services innovations for energy consumers on top of the developed solution.
- The solutions should make use of and contribute to the emerging common European data spaces in the fields of energy and mobility.

Carbon Capture, Utilization and Storage (CCUS)

D3-3-1: CO2 transport and storage demo projects, feasibility studies; synergies between projects

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative Budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to bring technologies that have reached at least TRL 6 to TRL 7 – 8.

Expected Outcome: The demo project shall use the CO2 from one or more capture sites and build or use a transport infrastructure, incl. shipping if needed, to the selected storage site where the CO2 will be injected. Practical experience with a demo project of that kind will increase the knowledge of the full CCS value chain including risk mitigation (financial, technical, and regulatory) taking into account the experience and results from previous research projects. Beside others this might include

for CO2 transport:

- impact of CO2 origin, composition and impurities;
- safety assessments and engineering design tools;
- transport of CO2 interoperability, incl. ships;
- reuse of pipelines, wells and platforms;

- Offshore hubs and clusters and concepts;
- environmental impacts and risks.

for CO2 Storage:

- preparation of storage sites (depleted oil and gas reservoirs, saline aquifers, basalt rocks, enhanced weathering);
- develop experience with site conformance monitoring and assessment;
- storage optimisation through development of a range of injection strategies;
- improve understanding of induced seismicity;
- prediction of plume under geophysical and geological uncertainty;
- flexibility of CO2 injection ramp up;
- environmental impacts and risks, including in the long term.

The demo project shall be the basis and orientation for future full size projects.

Scope: The development of regional CCUS clusters and their connection to European CO2 transport and storage infrastructures that enables cross-border cooperation across regions is crucial for reaching net-zero GHG emissions by 2050. The CCUS technology is not sufficiently operational in Europe yet. To overcome the remaining challenges, further R&I of CO2 transport and storage demo projects is needed.

Proposals will aim at the development of new demonstration projects connecting CO2 sources with potential storage sites. Proposals shall include a sound assessment of their environmental challenges and risks and feasibility studies focusing on the possible synergies between related projects. Proposals are expected to cover CO2 streams in the order of magnitude of 1Mio t CO2 per year.

CCUS is an integrated chain of technologies, comprising capture, transportation and/or use and geological storage of CO2. The next step in the application of CCUS is the development and deployment of CO2 transport and storage demo projects which show the practical feasibility of the required technologies. This is important to achieve greater efficiency in the transportation of CO2, notably collecting the emissions from hubs and clusters of industrial facilities and transporting the collective CO2 in shared open-access transportation infrastructure to a storage location. Under this approach, costs, risks and necessary support mechanisms can be better evaluated across the CCS value chain, as industrial installations, gas infrastructure companies and storage providers and operators will have clearly defined roles and responsibilities for delivering their tasks and will be compensated for collecting, transport and storage services. The benefits of the shared approach to the transport and storage infrastructure shall be evaluated with regard to economies of scale and possibly driving down unit costs for the CCUS value chain. The proposal should address possible barriers for deployment of technical or regulatory nature.

The key options for CO2 transportation are pipeline transport using new or repurposed infrastructure incl. shipping. The expected demo projects should

- assess the repurposing of existing pipeline networks and the creation of new CO2 transport infrastructure;
- identify and evaluate the benefits and costs (including economic, environmental, social);
- identify barriers to developing such an infrastructure and what action would be required to overcome these.

A successful CO2 transport and storage demo project might require a European transport and storage network with cross-border connections as not all countries have sufficient storage capacity for their CO2 emissions.

The selection of the storage site for the project shall be based on a detailed assessment. This shall include a geological characterisation, including faults and facture systems; analysis of initial stress field and geo-mechanical behaviour of the storage formations and seals under varying stress and pore-pressure conditions; estimation of storage capacity; accurate modelling of injectivity; overall storage risk assessment, including induced seismicity and blow-out or blockage during injection, and including proposed mitigation action. The assessment should include site-specific solutions for CO2 injection strategies, pressure management, mitigation of induced seismicity, and MMV (measurement, monitoring and verification).

For CO2 transport and geological storage, in particular onshore, public acceptance is paramount. Therefore, projects are expected to identify and engage relevant end users and societal stakeholders (such as civil society organisations, non-governmental organisations, and local associations) in deliberative activities, so as to analyse their concerns and needs using appropriate techniques and methods from the social sciences and humanities. This should include attention to, significant differences in potential regional consequences where the CO2 stored comes from power versus industry. Projects are strongly encouraged to join the EU CCUS knowledge sharing project network.

D3-3-2: CCU for the production of fuels

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative Budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to bring technologies that have reached at least TRL 4-5 to TRL 6-7 – see General Annex D.

Expected Outcome: Conversion of captured CO_2 is not only a means to replace fossil fuels, but also a promising solution for seasonal energy storage. There are still some scientific and technological challenges to overcome to be able to exploit CO_2 as a fuel feedstock, the main challenge being that the utilisation of CO_2 is limited by its low energy content, and the conversion process is highly energy intensive.

New solutions for the conversion of captured CO_2 from different sources to fuels will create new markets for innovative industrial sectors and diversify the economic base in carbon-intensive regions, as well as contribute to achieving a Circular Economy. The project should evaluate the possibility for industrial CO_2 use/reuse and the combination of processes (industrial symbiosis) and the integration of capture and conversion to combine and reduce stages.

Scope: Proposals will aim at the development of energy-efficient and economically and environmentally viable CO_2 conversion technologies, including energy storage and/or displacement of fossil fuels that allow for upscaling in the short to medium term. Proposals have to define ambitious but achievable targets for energy requirements of the conversion process (including catalytic conversion), production costs and product yields that will be used to monitor project implementation. Proposals have to include the potential for the proposed CCU solution(s) as CO_2 mitigation option through conducting an LCA (Life Cycle Assessment) in line with guidelines developed by the Commission, such as the Innovation Fund GHG methodology and the relevant ISO standards and the EU Taxonomy Regulation.

Technology development has to be balanced by an assessment of the societal readiness towards the proposed innovations. Relevant end users and societal stakeholders (such as civil society organisations, non-governmental organisations, and local associations) will be identified in the proposal, and involved in deliberative activities, so as understand and address their concerns and needs. This will be analysed during the project using appropriate techniques and methods from the social sciences and humanities, in order to create awareness, gain feedback on societal impact and advancing society's readiness for the proposed solutions. Projects should also explore the socio-economic and political barriers to acceptance and awareness with a view to regulatory or policy initiatives and include aspects of circularity and best use of resources. Projects are strongly encouraged to join the EU CCUS knowledge sharing project network.

D3-3-3: DACCS and BECCS for CO2 removal/negative emissions

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative Budget	The total indicative budget for the topic is EUR XX million.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 6 - 7 by the end of the project – see General Annex D.

Expected Outcome: The European Union aims at reducing its net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels, and at achieving carbon neutrality by 2050. Under the European Green Deal, the Commission has also adopted a zero pollution action plan, with a zero pollution ambition, and a Biodiversity Strategy. In view of achieving these ambitious targets it is appropriate to further explore the development of direct air carbon capture and storage (DACCS) and bioenergy carbon capture and storage (BECCS) as CO2 capture technologies in combination with CO2 storage, duly assessing their impacts on other environmental challenges.

The project shall develop highly innovative CCUS /carbon negative technologies leading to CO2 removal. It should enable the cost-effective deployment of technologies such as (DACCS), (BECCS) and enhanced mineralisation ideally linking them to industrial clusters with special emphasis of these technologies to safe CO2 underground storage and CO2 utilisation that could lead to negative emissions..

Project results are expected to contribute to at least one of the following expected outcomes:

- Improve existing or develop new materials for DACCS and BECCS technologies; or
- Address potential barriers to the incorporation of DACCS and BECCS technologies in existing CC(U)(S) concepts; or
- Make DACCS and BECCS technologies a viable option to make the EU carbon neutral by increasing the TRL levels and reducing cost of the different technological options.

Scope: This topic focusses on DACCS and BECCS, which are technologies that can help reaching climate neutrality by 2050 by creating the carbon sinks required to balance out residual emissions in 2050 and/or using carbon captured from the air or biomass as a raw material to replace other fossil raw materials.

The scope of this topic is to further the technological development of DACCS and BECCS, and addressing the environmental, social and economic challenges and benefits with the view of establishing this concept as a viable technology to fight climate change. The potential technologies require major technological breakthroughs, for example by

- Increasing knowledge of existing/develop new oxygen-tolerant catalysts for photo/electro-reductive conversion; or
- Developing thermal chemical conversion technologies for direct atmospheric carbon capture and conversion/storage; or
- Developing photo(electro)chemical conversion technologies for direct conversion of atmospheric CO2 to direct atmospheric carbon capture and conversion/storage to reduce the energy requirements of direct air capture.

Projects have to substantiate the potential for the proposed solutions as CO2 mitigation option by conducting an LCA in conformity with guidelines developed by the Commission, such as the Innovation Fund GHG methodology and the relevant ISO standards and the EU Taxonomy Regulation. This life cycle consideration should include the sustainability of biomass and the renewable origin of electricity but also assess other environmental dimensions (requirements for land, water; impacts on air and water quality, biodiversity; distances to major storage clusters, leakages etc.).

Technology development has to be balanced by an assessment of the societal readiness towards the proposed innovations. Relevant end users and societal stakeholders (such as civil society organisations, non-governmental organisations, and local associations) will be identified in the proposal, and involved in deliberative activities to understand and address their concerns and needs. This will be analysed during the project using appropriate techniques and methods from the social sciences and humanities, in order to create awareness, gain feedback on societal impact and advancing society's readiness for the proposed solutions. Projects should also explore the socio-economic and political barriers to acceptance and awareness with a view to regulatory or policy initiatives and include aspects of circularity and best use of resources. Successful projects will be encouraged to join the EU CCUS knowledge sharing project network.

Proposals that include research into the use of direct air capture for enhanced oil recovery will not be considered. Proposals shall take into account the related activities within the EU ETS Innovation Fund and the EU Catalyst Partnership. Within this topic it is expected to fund at least one project covering DACCS technologies and one project covering BECCS technologies.

<u>Cross-cutting</u>

D3-4-1. Place holder: Open Pilot Line/Test-Bed for hydrogen

Destination – Efficient, sustainable and inclusive energy use

This Destination addresses activities targeting the energy demand side, notably a more efficient use of energy as regards buildings and industry.

This Destination contributes to the following Strategic Plan's **Key Strategic Orientations (KSO)**:

- *C: Making Europe the first digitally enabled circular, climate-neutral and sustainable economy through the transformation of its mobility, energy, construction and production systems;*
- *A: Promoting an open strategic autonomy*[56] *by leading the development of key digital, enabling and emerging technologies, sectors and value chains to accelerate and steer the digital and green transitions through human-centred technologies and innovations.*

It covers the following **impact areas**:

- Industrial leadership in key and emerging technologies that work for people;
- Affordable and clean energy;
- Circular and clean economy.

The **expected impact**, in line with the Strategic Plan, is to contribute to the *"Efficient and sustainable use of energy, accessible for all is ensured through a clean energy system and a just transition"*, notably through

a. Technological and socio-economic breakthroughs for achieving climate neutrality and the transition to zero pollution of the **building stock** by 2050, based on inclusive and people-centric R&I (more detailed information below).

b. Increased energy efficiency in **industry** and reducing industry's Greenhouse Gas (GHG) and air pollutant emissions through recovery, upgrade and/or conversion of industrial excess (waste) heat and through electrification of heat generation (more information below).

This Destination has at its core the ambition to deliver on the research, innovation and technological developments needs to meet EU climate and energy targets, forward-looking policy implementation and long-term carbon neutrality objective. The Destination contributes as well (e.g. through the topics that support digitalisation and smartness of buildings) to the EU digital agenda. Though biodiversity is not in the focus of this Destination, the multiple impacts of the built environment on biodiversity (e.g. in the scope of renovation) should be considered.

[56] *'Open strategic autonomy' refers to the term 'strategic autonomy while preserving an open economy', as reflected in the conclusions of the European Council 1 – 2 October 2020.*

The Destination has a strong policy dimension – it is steered by EU policy action in the energy and climate domains, the European Green Deal overreaching policy priority, the Renovation Wave Strategy (for buildings topics), the Industrial Strategy, the Industrial Emissions Directive (for industry topics) and the forward-looking policy measures proposed in the Fit for 55 – Delivering European Green Deal package.

Highly energy-efficient and climate neutral EU building stock

The Destination will contribute to putting the EU on track for achieving climate neutrality of its building stock by 2050. It will deliver the solutions that can help increase buildings renovation rates, reduce energy consumptions, improve smart readiness, improve circularity, and improve users' comfort, well-being and health, while keeping housing affordable, in line with the objectives of the Renovation Wave and the revised Energy Performance of Buildings Directive. It will contribute to the uptake of digital and smart solutions in buildings and to improved energy flexibility, in line with the Action Plan on the digitalisation of the energy sector. The Destination's innovation will contribute to make the sector fit to support the achievement of higher ambition on energy efficiency under Fit for 55. The Destination's topics also embed the key aspects of the New European Bauhaus[57], on built environment sustainability, inclusivity and aesthetics (e.g. in relation to cultural heritage), and they are consistent with the EU roadmap and policy initiatives on digitalization in the construction sector and on sustainability of buildings (e.g. Level(s)). On climate, one aim will also be to enhance the role of buildings as carbon sinks in the voluntary market for carbon removals, in line with the upcoming Communication on Restoring sustainable carbon cycles and the Proposal for a regulatory framework for carbon removal certification.

The Destination also relies on the Built4People co-programmed partnership's broader action and is complementary to Driving Urban Transitions partnership and to the Mission on Climate Neutral and Smart Cities.

Main expected impacts:

1. The European buildings and energy sectors are able to effectively support higher EU ambition on energy efficiency and the transition to zero-emission buildings, with a stronger link between innovation in technology and practices, and policy drivers and instruments.
2. Building stocks continue to evolve to combine energy efficiency, renewable energy sources, storage, and digital and smart technologies, supporting the transformation of the energy system towards climate neutrality.
3. Buildings constructed and renovated see their performance enhanced across the board (energy, life-cycle emissions, indoor environment quality), with lower environmental impacts, and rates of holistic renovations continue increasing. Buildings are able to

[57] https://europa.eu/new-european-bauhaus/index_en

adapt to changing user needs for dynamic and more efficient use of building space and they are more resilient to climate change.

4. A higher quality, more affordable and inclusive, built environment mitigating climate change and preserving environment, safeguarding cultural heritage, considering sustainability, circularity and aesthetics, while ensuring better living conditions.

Industry

The Destination will contribute to putting the EU on track for achieving climate neutrality of the industrial sector by 2050, while also reducing other polluting emissions. It will deliver the solutions that can help a faster transition to renewable and low carbon energy sources for thermal energy generation, and a reduction of the energy consumption through waste heat recovery, storage and upgrade for reuse in other processes. These solutions will contribute to reduce GHG and polluting emissions and reinforce the frontrunner and competitive position of the EU industry. They are in line with the research and innovations areas identified in the Implementation Plan of the action of the Strategic Energy Technology (SET) Plan dedicated to 'energy efficiency in industry'.

The bulk of R&I dedicated to industry is covered in Cluster 4 (Digital, Industry and Space), and in particular by the private public partnership Processes4Planet focussing on process industries. In Cluster 5, this Destination focusses on the management of thermal energy in industry.

Main expected impacts:

1. Increasing energy efficiency in industry and reducing industry's Greenhouse Gas (GHG) and air pollutant emissions through recovery, upgrade and/or conversion of industrial excess (waste) heat and through the integration of renewable energy sources into more efficient and flexible systems for the generation of heat and cold for industrial processes.

Highly energy-efficient and climate neutral EU building stock

D4-1-1. Industrialisation of deep circular renovation workflows, with as-a-service solutions for sustainable, circular renovation (Built4People)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

- Streamlining resource-efficient nearly zero-energy performance renovation processes;
- Renovations with reduction of at least 30 % waste, 25% cost, and 30% work time (to 1-2 days per dwelling/building unit), compared to current deep renovation processes;
- Reduced performance gap between as-built and as-designed (difference between theoretical and measured performance), and higher construction quality;
- Innovative, tailored business models for deep renovation, generating economies of scale and contributing to an increased rate of renovation;
- Enhanced user comfort and Indoor Environmental Quality.

Scope: In line with the Renovation Wave and in order to meet long-term climate and energy targets, more action is needed to increase the rate and depth of building renovation. Several recent projects and calls have focused on prefabrication for deep renovation, but more work is needed to develop innovative, seamless workflows from design through to off-site prefabrication, to installation, construction on-site, maintenance and future dismantling, reuse and recycling of pre-fabricated elements, duly considering life cycle performance and the potential to use the buildings as carbon sinks.

Proposals are expected to address all of the following:

- Investigate innovative approaches for industrialised deep circular renovation, covering the whole workflow from design through to off-site prefabrication, installation, construction on-site and strategies for maintenance, operation and end of life.
- Ensure the proposed approaches aim to achieve the highest level of energy performance (at least NZEB level) with a view toward zero-emission buildings, and of indoor environment quality, keeping costs in an attractive range for owners and investors.
- Make use of innovative processes and technologies, including those delivered by previous research, such as design based on circularity principles, prefabricated

components, and digital tools that allow to optimise workflows (cost, time, quality, resource use).

- Demonstrate a seamless integration of the proposed approaches with state-of-the-art digital technologies for construction and renovation (Building Information Modelling, Digital Twins, etc.).

- Select processes and technologies that can be easily tailored to give a maximum potential for rapid and broad deployment at European level.

- Investigate business models in view of mass deployment and Europe-wide impact.

- Apply the proposed workflows to at least five large-scale demonstrations to assess the proposed approaches for a variety of buildings typologies representative of the European building stock, ensuring the most adequate coverage of climatic conditions. The demonstrations can be either single buildings or clusters of buildings, and at least three of the demonstrations have to be residential buildings.

- Contribute to the activities of the Built4People partners and to the Built4People network of innovation clusters.

D4-1-2. Robotics and other automated solutions for assembly, renovation and maintenance in a sustainable built environment (Built4People)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Technology Readiness Level	4-5

<u>Expected Outcome</u>: Project results are expected to contribute to all of the following expected outcomes:

- Reduction of construction and renovation time on-site;

- Reduction of errors in construction and renovation works;
- Improved resource efficiency;
- Reduction of construction and renovation costs;
- Reduction of greenhouse gas emissions resulting from, and improved energy efficiency of the works;
- Reduced environmental impact of construction works, including pollution, particulate matter[58] and noise, in the immediate vicinity;
- Reduction of waste generated from the works.

Scope: The transformation of the built environment should take place in a way that minimises the environmental impact of the works themselves. With the increasing rollout of highly energy efficient, sustainable buildings and deep renovation, there is a growing need for the development of robotic and automated solutions to support sustainable building construction, renovation and maintenance processes that are less disruptive, cleaner and faster.

Proposals are expected to address all of the following:

- Investigate the use of robotic systems (including those used for 3D printing) and automation for construction and deep renovation, in order to reduce time of construction and renovation works, reduce construction errors, as well as facilitate maintenance, also minimising the impact of the works on the surrounding built environment.
- Explore the potential for lower construction costs through automation and robotics resulting from increased speed, improved resource efficiency and avoidance of errors.
- Develop robotic and automated design and construction techniques that increase energy efficiency and reduce greenhouse gas emissions from renovation works on-site.
- Develop approaches that use digitally assisted, intelligent design to improve resource efficiency and safety, reduce waste, and reduce construction time.
- Investigate the use of automated technologies for surveying, inspection and monitoring of the site.
- Investigate the use of automated support to augment workers' capability and safety (e.g., lift robots, exoskeletons, automated construction site monitoring).
- Demonstrate the proposed solutions in at least three demonstrations to assess the proposed approaches for a variety of buildings typologies representative of the

[58] https://www.eea.europa.eu/help/faq/what-is-particulate-matter-and

European building stock. The demonstrations should address both new construction and renovation.

- Contribute to the activities of the Built4People partners and to the Built4People network of innovation clusters.

D4-1-3. BIM-based processes and digital twins for facilitating and optimising circular energy renovation (Built4People)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results shall contribute to all of the following expected outcomes:

- Reduced buildings construction and renovation time and costs;
- Demonstrated improvement of buildings material reuse and recycling;
- Demonstrated improvement of buildings performance (energy, sustainability including whole life-cycle carbon and the potential to store carbon in built works, comfort, health and well-being, and accessibility);
- Enhanced, interoperable and accessible buildings information across the lifecycle;
- Demonstrated improvement of interoperability with existing Building Information Modelling (BIM) and Digital Twin software;
- Broader application of BIM and Digital Twin solutions, in particular within SMEs.

Scope: To improve Building Information Modelling and Digital Twinning over the full life cycle of buildings, including construction and renovation of buildings, towards enhanced energy efficiency and sustainability and in compliance with circular economy and resource efficiency principles.

Proposals are expected to address all of the following:

- Develop and integrate solutions based on BIM and Digital Twins to support the whole buildings life cycle from design to deconstruction and reuse, including operation;
- Ensure the solutions developed address all the following aspects:
    - Supporting optimal, adaptable and reversible building design for energy efficiency, circularity and sustainability.
    - Allowing to track buildings materials and construction products, and supporting cost-effective deconstruction and reuse, recycling and recovery of building materials at end of life.
    - Integrating buildings monitoring data from sensors and IoT devices into an interoperable Digital Twin for automated, optimised building performance monitoring and management, and preventive maintenance.
    - Enabling buildings data interoperability and integrity across the life cycle, in particular to reliably assess and track building performance over the life cycle; enabling tailored data access for all life cycle's stakeholders (architects, engineering companies, contractors, building owners, financing institutions, etc.).
    - Easiness of use and cost effectiveness, in particular for SMEs and companies with limited experience in digital solutions, and high potential for replication and commercialisation.
- Apply the solutions delivered on a set (at least three) of real-life residential and non-residential building construction and renovation projects which, taken together, allow to demonstrate the potential of the solutions across all aspects listed in the topic and across the life cycle.
- Ensure that the demonstrations of the solutions delivered:
    - Cover at least three different countries, with diverse climatic conditions;
    - Involve local and regional values chains, in particular SMEs, based on participatory approaches to increase innovation acceptance;
    - Result in clear and, where relevant, quantified and measurable indicators on the improvements due to the use of the solutions, for all aspects listed in the topic and across the life cycle.
- Contribute to the activities of the Built4People partners and to the Built4People network of innovation clusters

D4-1-4. Design for adaptability, reuse and deconstruction of existing buildings, in line with the principles of circular economy (Built4People)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Technology Readiness Level	4-5

Expected Outcome: Project results shall contribute to all of the following expected outcomes:

- Improved adaptability of buildings and building units to new uses;
- Increased reuse and recycling of building elements and products;
- Extended service life of buildings;
- Increased awareness on best practices for design for adaptability, reuse and deconstruction.

Scope: Based on the integration of innovative tools, products and techniques, to enable renovation that embeds the principle of extending the service life of buildings, and facilitate adaptability to changing user needs (e.g. for optimal use of indoor space), reuse, and deconstruction, in a life-cycle optimisation and circular economy perspective.

Proposals are expected to address all of the following:

- Validate renovation approaches based on the integration of innovative tools, products and techniques that facilitate deconstruction and reuse, based on life-cycle approaches across the value chain.
- Ensure the solutions validated:
    - consider the adaptability of buildings and building units to new uses;
    - improve the ease of reuse of construction elements and products from existing buildings;

    - develop building elements and products that can be disassembled and reused, including those made from CO2-storing materials such as sustainably sourced long-lived bio-based materials and products and, innovative lower emission materials /aggregates;
    - address all components of buildings, including structural elements, envelopes, interior fixtures and fittings, and technical building systems;
    - are rooted in local and regional value chains, based on participative approaches for social acceptance of innovation, in particular with regard to the workforce's practices and skills;
    - can flexibly adapt to local / regional sourcing of innovative products and materials to increase replication;
    - address climate change mitigation, minimising emissions;
    - allow to minimise any negative impacts of pollution and biodiversity loss from renovation and construction works.
- Validation of the solutions in a relevant environment (real-life or close to real-life) that:
    - Covers residential and non-residential projects;
    - Covers at least three different countries, with diverse climatic conditions;
    - Involves local and regional values chains, in particular SMEs, based on participatory approaches to increase innovation acceptance;
    - Results in clear and, where relevant, quantified and measurable indicators on the improvements due to the use of the solutions.
- Deliver guidance and recommendations for technology providers, regulatory authorities and standardisation bodies, and define and implement ambitious dissemination actions, to promote the approaches demonstrated and support their replication.
- Where relevant, contribute through specific and targeted actions to standardisation and regulatory evolutions that can foster reuse and deconstruction of buildings materials and products.
- Contribute to the activities of the Built4People partners and to the Built4People network of innovation clusters.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

D4-1-5. Innovative uses of lifecycle data for the management of buildings and buildings portfolios (Built4People)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Increase in the availability of key energy and environmental performance indicators from new or improved building management systems that go beyond energy management to life-cycle approach (e.g. environmental performance, circularity, comfort, accessibility, safety, resilience and climate risk vulnerability).
- Improved tools for the planning and management of building assets and portfolios of buildings including energy management, environmental performance, renovation optimisation and investment planning.
- Increased availability and access to lifecycle data of buildings and buildings portfolios and enhanced interoperability and synergies among data sharing platforms.

Scope: European buildings are producing an increasing number of data on energy and non-energy uses. More and better data can lead to enhanced consumer information, contribute to an effective management of energy grids and support the creation of innovative energy services, new business models and financing schemes for distributed clean energy. Data is also a key enabler for reliable and effective policymaking, e.g. for climate policies. Several recent projects have focused on developing big data facilities and data analytics tools to monitor the energy performance of buildings based on energy related data. More work is needed to integrate energy data with lifecycle data (e.g. GHG emissions and removals, materials, water, health, comfort, life cycle cost and value, etc.), in order to optimise the performance of buildings and buildings' portfolios across the board and support the decision making of owners/tenants/developers to transform existing and planned physical assets (buildings or buildings' assets, e.g. distributed energy generation, e-mobility recharging infrastructure, micro-grids, building systems).

Proposals are expected to focus on one or more of the following actions:

- Develop new or upgrade existing building management systems enhanced with data analytics. The developed systems should take into account buildings monitoring data (e.g. from embedded sensors/actuators), users' preferences (e.g. related to comfort), and surrounding environmental conditions (e.g. urban density, micro-climate, etc.).
- Develop new or upgrade existing decision support tools for the management of building assets and portfolios of buildings. The developed tools should be able to deliver energy (e.g. energy monitoring, renovation optimisation) and non-energy services (investment planning, risk assessment – e.g. risk-related, fault detection, predictive maintenance, surveillance & safety, occupancy satisfaction). The tools should be co-developed with the potential users (e.g. facility managers, fund managers etc.) and tested in real market conditions.
- Develop new or upgrade existing data sharing platforms including lifecycle data of buildings or buildings portfolios. The platforms should connect relevant market actors (technology providers, developers, aggregators, DSOs, ESCOS) with relevant user groups (consumers, energy communities), policy makers and the financial sector and offer innovative services (e.g. flexibility, prediction, investment planning etc.). The platforms should be co-developed with the participation of the potential users groups and tested in real market conditions.
- Develop new or upgrade existing real-time digital twinning tools to optimise operational energy and environmental performance.
- Contribute to the activities of the Built4People partners and to the Built4People network of innovation clusters.

Proposal should implement at least three large -scale pilots to demonstrate the chosen system. The pilots should cover a variety of building typologies (residential, commercial, public etc.) and use cases (energy monitoring, renovation optimisation, investment planning, risk assessment etc.)

D4-1-6. Solutions for the identification of vulnerable buildings and people-centric built environment, and for improving their resilience in disruptive events and altered conditions in a changing climate (Built4People)

Specific conditions	
Expected EU	The Commission estimates that an EU contribution of XX million

contribution per project	would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results shall contribute to all of the following expected outcomes:

- Increased awareness of approaches for the identification and categorisation of the vulnerability of existing and future buildings and infrastructures.
- Increased number of demonstrated innovative solutions to improve safety and resilience of the built environment, to extreme climatic events, and other natural disasters, as well as to altered conditions due to climate change.
- Increased use of relevant data such as weather forecasts or catastrophe warnings by monitoring and management systems in the built environment (e.g. to launch automatic emergency protocols to warn and protect buildings users).
- Improved understanding of new business models allowing to optimise the costs of resilience, taking into account asset management and lifecycle approaches.
- Increased awareness of building occupants and other key stakeholders on the available solutions in case of extreme climatic events, and natural disasters.

Scope: Buildings should contribute to an integrated approach for a safe and healthy people-centric built environment at block, district and urban level. The built environment needs to be adapted, designed, and constructed for combating the effects of Global Warming (increased heat island effect, increased cooling demands, water scarcity, etc.) and for providing safety and resilience to adverse climatic events at a larger scale, whilst ensuring their connection and integration with energy, ICT and transport infrastructures.

Proposals are expected to address all of the following:

- Develop approaches for the identification and categorisation of the vulnerability of existing, and future, buildings and built environment, where possible using and/or further developing existing vulnerability assessment methodologies.

- Develop innovative designs, materials and solutions to improve safety and resilience of the built environment to extreme climatic events (heat waves, floods, category 5 storms, etc.), and which may also be relevant in other natural disasters, such as earthquakes depending on the geographical location of the buildings.

- Where appropriate, ensure the proposed approaches and solutions address deep renovation, linking to relevant instruments for awareness and advice of building owners (e.g. renovation passports) in order to gradually adapt buildings to climate change in an adaptation pathways approach.

- Explore the use of relevant data, such as weather forecasts or catastrophe warnings, by monitoring and management systems in the built environment (e.g. to launch automatic emergency protocols to warn and protect buildings users).

- Investigate the potential of asset management and life cycle approaches to optimise costs of resilience (e.g. to climate and environmental factors).

- Ensure that the whole value chain from design over construction to end of life is covered.

- Demonstrate the solutions in at least 5 large-scale demonstrators, at block or district level and including where appropriate the connections to energy, ICT and transport infrastructures, in diverse geographical areas, with various local environmental, social, and economic conditions.

- Demonstrate that the proposed solutions also lead to improved accessibility for persons with disabilities, an improved local environment, and minimise any negative impacts on biodiversity.

- Contribute to the activities of the Built4People partners and to the Built4People network of innovation clusters.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

D4-1-7. Demonstrate built-environment decarbonisation pathways through bottom-up technological, social and policy innovation for adaptive integrated sustainable renovation solutions (Built4People)

Specific conditions	
Expected EU contribution per	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless,

project	this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results shall contribute to all of the following expected outcomes:

- Demonstrated innovative solutions and packages for sustainable construction and renovation;
- Demonstrated built-environment decarbonisation pathways towards zero-emission buildings considering the whole value chain at local or regional level;
- Increased engagement and participation of the whole value chain in local and regional innovation clusters;
- Reduced time from first demonstration to market of sustainable renovation solutions;
- Increased awareness and improved access at a local or regional level to information on construction products for reuse and circular businesses;
- Creation of new business opportunities with reduced risk for investment in the circular economy;
- Enhanced engagement amongst communities, businesses, local and regional governments, and the extended construction value chain, e.g. materials and equipment, manufacturers, construction companies.

Scope: To improve the energy efficiency, circularity and sustainability of the built environment there is a need to develop and apply integrated approaches that demonstrate, in practice, achievable pathways for decarbonisation of the building stock through a whole life carbon approach, including temporary carbon storage in built works (e.g. thanks to wood-based products). This means developing and integrating new design techniques allowing for deconstruction and reuse; new products and components that can be dismantled and reused; and new products and components for construction works that incorporate reused and recycled elements and materials. In addition, there is a need to deploy and test through a value chain approach the enabling conditions that facilitate the integration of the innovations outlined above in planning, design, budgeting, procurement, construction practice, insurance, and related administrative and regulatory processes.

Proposals are expected to address all of the following:

- Demonstrate a value chain approach and pilot decarbonisation pathways in at least 5 deconstruction/re-use/construction demonstrators and supply chain approaches of market-scale renovations.
- Demonstrate low disruptive and simpler construction and retrofitting processes, which facilitate a life cycle-based approach that fosters alignment with EU Level(s) framework indicators.
- Test the enabling conditions (technological, social, and policy) that can boost innovation and reduce time from research to market of sustainable renovation solutions.
- Establish and operate demonstrative regulatory sandboxes that allow to deploy and test innovation pathways for decarbonisation of buildings at a meaningful scale with the involvement of the whole value chain at local level.
- Where relevant, explore fast tracking of cost-effective standardisation and certification of innovation sustainable renovation solutions.
- Where relevant, investigate non-standard contractual relationships within the design-construction-client project team, including 'as a service' approaches for the built environment.
- Develop solutions that can stimulate the market for reused construction products at a regional level in support of the Renovation Wave and which can contribute to increased rate and depth of renovation in order to reach climate neutrality by 2050.
- Develop design solutions that address inclusion and accessibility, and leading to documented improvements in comfort and health aspects, whilst reducing emissions from the built environment and enhancing climate change resilience.
- Contribute to the activities of the Built4People partners and to the Built4People network of innovation clusters.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

D4-1-8. Fast-tracking and promoting built environment construction and renovation innovation with local value chains (Built4People)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	CSA
Technology Readiness Level	N/A
Eligibility criteria	Projects must cooperate closely with the ECTP network of National Technology Construction Platforms and cross-border/cross-sectoral clusters, as well as with the World GBC European network.

Expected Outcome: Project results shall contribute to all of the following expected outcomes:

- Expansion and strengthening of the Built4People network of Construction Innovation Clusters.
- Increased awareness and improved access at a local or regional level to research outcomes for sustainable built environment construction and renovation.
- Increased engagement and participation of the whole value chain in local and regional construction innovation clusters.
- Strengthened, long-lasting and multi-disciplinary networking and collaboration on locally rooted, bottom-up innovative holistic solutions for a sustainable built environment.
- Enhanced engagement amongst communities, businesses, local and regional governments, and the construction industries and associated supply chains.
- Establishment and reinforcement of European value chains in sustainable construction and renovation.
- Creation of new business opportunities with reduced risk for investment in innovative built environment construction and renovation.

- Reduced time from research to market of innovative sustainable construction and renovation solutions.

- Increased public and private co-financing of innovation in the field of innovative sustainable built environment.

Scope: For effective fast-tracking and promotion of built environment construction and renovation innovation with local value chains, nascent construction innovation clusters need to link with regional/national innovation hubs and clusters. This will strengthen multi-disciplinary networking and collaboration amongst all actors of local and regional construction ecosystems and reinforce European value chains. A long-term network structure is needed, based on an appropriate business model and governance, to support these clusters and give them capacity to nurture and help deliver public and private investments in sustainable construction and renovation innovation.

Proposals are expected to address all of the following:

- Delivery of a long-term network structure for the Built4People construction innovation clusters.

- Support adoption of the enabling conditions (technological, social, and policy) that can boost innovation and reduce time from research to market of sustainable renovation solutions.

- Monitor growth of Built4People construction innovation clusters and assess their effectiveness for reducing the time from research to market of sustainable renovation solutions.

- Stimulation of co-financing of innovation in the field of innovative sustainable built environment.

- Disseminate exemplary practices for fast tracking of cost-effective standardisation and certification of innovative sustainable renovation solutions.

- Prepare the value chain at a local/regional level for uptake of innovative sustainable construction and renovation solutions in support of the Renovation Wave and the increased rate and depth of renovation, also post 2030, in order to reach EU-wide climate neutrality by 2050.

- Promote design solutions that address inclusion and accessibility, and leading to documented improvements in comfort and health aspects, whilst reducing emissions from the built environment and enhancing climate adaptation resilience.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

D4-1-9. Digital solutions to foster participative design, planning and management of buildings, neighbourhoods and urban districts (Built4People)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results shall contribute to all of the following expected outcomes:

- Greater engagement of representative groups of end users as well as citizens of the impacted urban context.
- Increased acceptance and uptake of sustainable deep renovation solutions in the built environment.
- Reduced energy and mobility poverty.
- Increase in plans for climate neutral and sustainable, aesthetic and inclusive built environments with enhanced climate adaptation and resilience.
- Enhanced climate change adaptation and resilience in built environments.

Scope: The transition to a climate-neutral society requires that Europe's building stock also becomes climate-neutral. At the same time, Europe's building stock has to become climate-resilient. This requires a comprehensive approach beyond individual buildings, namely at the level of neighbourhoods or urban districts. However, the decarbonisation of the built environment and its adaptation to a changing climate and to societal needs in terms of comfort, accessibility, inclusiveness and aesthetics cannot happen without active participation of the buildings' users and occupants, individual / collective property owners, and energy communities as beneficiaries of the value chain. Professionals, such as project developers, architects, planners and statutory authorities, require solutions that develop, analyse, model, visualise and present a multitude and complex set of information in such a way that facilitates such co-design processes. This topic focuses on the development of digital solutions for a stronger participation of end users, citizens and other relevant stakeholders in the design, planning and management of the renovation of existing buildings, neighbourhoods and districts.

Proposals are expected to address one or several of the following:

- Digital solutions that facilitate participative design and planning through visualisation, analysis and engagement with data that is directly relevant to building users as well as citizens in the surrounding urban area (including e.g. Virtual Reality / Augmented Reality, simulations and scenario modelling).
- Digital solutions that gather and evaluate feedback from building users and occupants, and feed this back into development plans.
- Digital solutions that develop models of buildings, neighbourhoods or urban districts taking into account the results of participative processes.
- Digital solutions that analyse and model different scenarios for to-be-renovated buildings, neighbourhoods and districts in terms of: energy use and generation; impact on the energy grid; provisions for active and electric mobility, and sustainable delivery solutions; life-cycle environmental and micro-climatic impacts, and; socio-economic impacts for citizens, building users, owners and occupiers.

In addition, proposal should address all of the following:

- Address aspects of climate-neutrality and climate-resilience, respecting the 'energy efficiency first' principle.
- Ensure the digital solution complements, builds on and/or uses existing tools and standards recognised by the market.
- Engage citizens, end users of the tools and other relevant stakeholders involved in the design, planning and management of urban development projects in the development process of the digital solution.
- Ensure the digital solution offers different means to exchange information and provide input that are tailored to the specific needs of laypersons, including vulnerable, minority and disadvantaged groups as well as persons with disabilities and older persons.
- Test the prototype in at least three real-life urban development projects to apply, evaluate and refine the digital solution and inform its market launch and / or commercialisation strategy.
- Contribute to the activities of the Built4People partners and to the Built4People network of innovation clusters.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

D4-1-10. Design of buildings, infrastructure, multi-modal hubs and public spaces for people accessibility and inclusiveness (Built4People)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Improved accessibility[59] for persons with disabilities and older persons to buildings and other artefacts and spaces of built environment.
- Improved comfort and easy access and mobility for larger shares of the population.
- Increased uptake of accessible and inclusive active mobility solutions (walking and cycling) in support of healthy and sustainable lifestyles.
- Improved sense of inclusiveness[60] and social cohesion in larger shares of the population.

[59] Accessibility is meant as the removal and prevention of barriers that hinder the participation of persons with disabilities in society on equal basis with others. In this case the focus is on barriers in the built environment.

[60] Inclusiveness is meant as environments that reflect the diversity of society with full respect of the human rights and fundamental freedoms of all inhabitants.

- Improved consideration of accessibility and inclusiveness in the transformation of the built environment towards sustainability, climate change mitigation and adaptation, in line with energy and climate ambitions.

- Reduced energy consumption and GHG emissions.

Scope: Proposals are expected to focus on innovative planning and design tools for new and existing buildings and/or infrastructure and/or multi-modal hubs and/or public spaces with the triple aim of improving comfort (e.g. improving air quality, reducing noise or vibrations), making them accessible for persons with disability and/or older persons and, supporting the transformation of the built environment towards sustainability, climate change mitigation and adaptation. Overall, final solutions should reflect more inclusiveness and cohesion in society in order to support a fair green transition.

The focus will be on the different facilities of the built environment that are open to the public. Beside comfort, proposals should address design paradigms ensuring flexibility for accessible adaptations (e.g. for addressing the changing needs of people with increasing disabilities and reducing mobility).

The proposals should investigate solutions for buildings and multimodal hubs aiming at removing barriers, enhancing accessibility, improving storage of (cargo-)bicycles/charging possibilities for electric (cargo-) bicycles in an inclusive way (e.g., taking into account the specific needs of elderly, multi-generational groups, and people with special needs).

The design of public spaces to promote soft and active modes of mobility through attractive, safe and green infrastructure for healthier and environmentally friendly lifestyles lowering carbon emissions and noise pollution is also in the scope.

Special attention is to be paid (for persons with disabilities and older persons) to the accessibility of new digital tools used to address among others energy efficiency and comfort, in order to ensure that this segment of the population are also able to participate fully in the built environment on an equal basis with others .

Planning tools should enable identifying the optimal solutions for each location in terms of position and access and in terms of communication among locations, including for persons with reduced mobility. Designs concepts should make the facilities of the built environment under consideration accessible for persons with disabilities or with specific needs and therefore inclusive for all.

Innovative methods to ensure and facilitate the implementation of accessibility at all stages of design and construction processes, as well as the monitoring and testing of results should be developed. In addition, the involvement of persons with disabilities in these processes and the creation of "accessible" jobs opportunities will be of added value.

Participation of / co-creation with relevant societal stakeholders should be part of the action. To this end, this topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

Proposals are expected to contribute to the activities of the Built4People partners and to the Built4People network of innovation clusters.

D4-1-11. Low-disruptive renovation processes using integration of prefabricated solutions for energy-efficient buildings

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results shall contribute to all of the following expected outcomes:

- Reduction of on-site construction activities to 1-2 days per dwelling/building unit.
- Cost reduction of at least 25% compared to conventional renovation processes.
- Significant reduction of dust, noise and waste on the construction site compared to conventional renovation processes.
- Significant reduction in occupant disturbance during the renovation.
- Improved levels of occupancy comfort (e.g. Indoor Air Quality and Indoor Environmental Quality) after renovation.
- Insights into new and attractive business models for faster and less disruptive construction and retrofitting processes for energy-efficient buildings.
- Reduction of negative impacts of renovation on biodiversity, considering as well adaptability (e.g. to climate change, different use, evolving societal needs, etc.) and resilience of buildings to disruptive events.

Scope: Low-disruptive renovation processes, using prefabricated modules that are quick and easy to apply can play an important role in increasing the renovation rate of the European building stock. Renovation processes should cover the whole workflow from design through to offsite manufacture, installation, compliance checking on site and end strategies for maintenance, operation and end of life.

Proposals are expected to address all of the following:

- Develop streamlined processes for deep energy-efficient renovation to at least NZEB performance levels using prefabricated modules.
- Use relevant available technologies to reduce quality gaps between the off-site manufacturing and on-site deployment of prefabricated modules.
- Develop processes for seamless integration of prefabricated solutions into a variety of existing constructions (e.g. various existing wall materials, presence of balconies and overhangs, existing piping in the way etc.).
- Ensure the processes minimize the disturbance for building owners, tenants and users, through a considerable time reduction of on-site construction activities, reduced impact in terms of the unavailability of the building and its main functionalities, and a minimal impact on occupancy comfort during the renovation process.
- Include at least five demonstrations covering different building categories (residential or tertiary) and various building typologies, such as single or multi-storey, single or multi-use, etc.
- Demonstrate less-disruptive retrofitting processes that are more attractive and more cost-effective for building owners, tenants and users.

D4-1-12. Innovative cost-efficient solutions for zero-emission buildings

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology	6-8

Readiness Level	

Expected Outcome: Project results shall contribute to all of the following expected outcomes:

- Demonstrated cost-effectiveness of zero-emission buildings construction.
- Enhanced productivity of construction compared to standard practice.
- Reduced embodied emission and increased carbon storage, enhanced energy performance.
- Increased awareness on zero-emission construction best practices.
- Enhanced circularity of construction.

Scope: To demonstrate that high-quality and affordable zero-emission buildings, in line with the Proposed Revision of the Energy Performance of Buildings Directive, can be delivered and mainstreamed. With new buildings already required to be nearly-zero energy buildings, the focus is on how to achieve zero or positive energy standards and how to reduce embodied emissions, also storing CO_2 where possible (using recycled, zero-carbon, or sustainably sourced carbon-storing construction materials).

Proposals are expected to address all of the following:

- Demonstrate innovative construction approaches solutions based on integrated existing solutions into standardised packages for a cost-effective construction of (new) zero-emission buildings, in line with the Energy Performance of Buildings Directive.
- Ensure the approaches demonstrated:
  - Allow to achieve zero or positive energy standards and to reduce embodied emissions, also storing carbon where possible, using recycled, zero-carbon or sustainably sourced carbon-storing construction materials;
  - rely on mature construction products and materials, and technical building systems, seeking to deliver solutions that are ready for application and use;
  - address all components of buildings (envelope, technical building systems, on-site[61] renewable energy – e.g. BIPV – and, where relevant, electric vehicle charging points);

[61] 'on-site' means the premises and the land on which the building is located and the building itself.

- are rooted in local and regional value chains for sourcing of buildings components and for involvement and upskilling of local and regional businesses;
- are tailored for the applicable regulatory framework: EU, national, and (where relevant) regional and local level;
- have strong potential for replication across Europe, in particular by construction SMEs.

- Demonstrations that include at least five real-life new construction projects.
- Ensure that the demonstrations:
  - Cover at least five countries, with diverse climatic conditions and architectural patterns;
  - Involve local and regional values chains, in particular SMEs, based on participatory approaches to increase innovation acceptance;
  - Lead to clear and, where relevant, quantified and measurable indicators on the results achieved.
- An ambitious EU-wide dissemination roadmap addressing all relevant stakeholders (in particular businesses and authorities) to:
  - promote the zero-emission buildings innovative construction approaches demonstrated;
  - share guidance and recommendations on best practices for zero-emission construction;
  - provide feedback to policy makers at EU, national, and (where relevant) regional and local level.

D4-1-13. Future-proofing historical buildings for the clean energy transition

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.

Type of Action	RIA
Technology Readiness Level	4-5

Expected Outcomes: Project results shall contribute to all of the following expected outcomes:

- Reduction of energy demand by at least 60%, preserving historical values.
- Reduction of waste.
- Improved lifetime renovation cost effectiveness.
- Improved comfort, Indoor Air Quality and Indoor Environmental Quality.
- Significant reduction in maintenance costs.
- Where possible, successful installation of RES, integrated in a way that respects the specificities of historical buildings.
- Proven effectiveness and replicability of the proposed solutions.

Scope: Around a quarter of the existing building stock in Europe was built prior to the middle of the last century. Many such buildings not only reflect the unique character and identity of European cities, but also include essential infrastructure for housing, public buildings etc. A significant number of these have a poor energy performance, continue to use conventional and inefficient fossil fuel-based energy systems and are costly to refurbish. Furthermore, changes in building use and higher indoor comfort expectations than in the past are driving up energy demand, a particular challenge when historical buildings are used or converted for residential, educational, retail, office or other purposes. Many recently developed renovation approaches are not adapted to the specific requirements of historical buildings. The process of future-proofing these buildings for the clean energy transition faces additional challenges compared to other buildings, as it has to take into account architectural restrictions, as well as the specificities of the materials used in their construction, which does not respond well to renovation techniques used in modern buildings.

Proposals are expected to address all of the following:

- Deliver standardised renovation approaches and solutions for the deep renovation of historical buildings to improve their energy performance, indoor air quality, comfort and climate resilience, while respecting their architectural and cultural specificities, materials and traditional construction techniques.
- Target building types constructed prior to 1945 that have restrictions regarding changes of their envelope (walls, window, doors, and/or roof). (Buildings of nationally

or internationally recognised significant cultural heritage built after this date may also be considered.).

- Standardised renovation approaches and solutions that are directly replicable for other buildings of the same building type, which should represent a share of at least 1% of buildings in the specific country where they are located.
- Reduce energy demand in a cost-effective way.
- Explore both internal and external insulation solutions, and where possible incorporating adaptable interventions, plug and play technical building systems, and/or renewable energy services.
- Employ both novel materials and techniques suitable for these buildings, but also adapt and improve traditional construction techniques or materials.
- Improve the comfort of occupants and lower the maintenance costs for building owners.
- Where applicable, involve relevant conservation authorities.
- Validation of the solutions in a relevant environment (real-life or close to real-life) that:
  - Covers at least three different countries, with diverse climatic conditions.
  - Results in clear and, where relevant, quantified and measurable indicators on the effectiveness and the potential for replication of the solutions.

D4-1-14. Interoperable solutions for positive energy districts (PEDs), including a better integration of local renewables and local excess heat sources

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results are expected to contribute to the following expected outcomes:

- Increased availability of interoperable solutions for planning and managing Positive Energy Districts (PEDs).
- Improved integration of energy (e.g. distributed renewable energy generation, waste heat utilisation) and non-energy sectors (e.g. mobility) within PEDs.
- Increased availability of tools and guides for PED design, development and management.
- Increased social entrepreneurship and citizen participation in energy communities.
- Increased participation of consumers and energy communities in the value chain of the energy system.

Scope: Recent projects have demonstrated positive energy districts, but there is a need to demonstrate fully interoperable solutions that include improved energy efficiency coupled with a better integration of local renewables and local excess heat sources within the district. In parallel, the interoperability of positive energy districts with the urban and renewable energy system in which they are embedded needs to be enhanced through effective solutions that will allow interaction and integration between buildings, the users and the regional energy, mobility and ICT systems.

Projects are expected to address all of the following:

- Develop solutions (products, tools, etc.) for planning and managing assets (e.g. buildings, energy systems, mobility systems, ICT) in positive energy districts.
- Develop tools and methods for planning and designing PEDs, that support PED developers and managers to optimise the mix of PED solutions depending on the local conditions.
- Develop data exchange platforms (heat & electricity) and technologies to integrate buildings with energy markets (e.g. flexibility market), allowing buildings to contribute effectively to grid stabilisation at district / city level.
- Develop methodologies and/or planning tools for the optimal integration of distributed renewable generation and excess heat at district (or building) level.
- Develop innovative business models for integration of PEDs in the energy markets including technological, financial and regulatory aspects.
- Deploy and test certification and standardisation frameworks for interoperable solutions in positive energy districts.

- Pilot the proposed solutions in at least three large scale PEDs to promote replication, upscaling and mainstreaming.

To ensure interoperability and integration into the grid, projects should make use of operational end-to-end architectures, digital platforms and other data exchange infrastructure for the energy system being developed under ongoing Horizon 2020, Horizon Europe as well as under other EU programs such as the Digital Europe Program, when addressing communication and data exchange between inverters and other components, other appliances and the electricity network.

The selected projects are expected to contribute to relevant BRIDGE[62] activities.

D4-1-15. Smart grid-ready buildings

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Improved integration of buildings with energy carriers (e.g. electricity grid, district heating networks) and non-energy services (e.g. mobility).
- Improved buildings flexibility for grid and network management.
- Increase in renewable energy production and storage at building level.
- Empowerment of end-users by having increased control over their buildings' energy services and contracts (consumption, production, storage, flexibility).

[62] h2020-bridge.eu

- Enhancement of the smart readiness of buildings as rated by the smart readiness indicator.

Scope: There is a need to deliver solutions to improve the interoperability of European buildings with energy carriers (e.g. electricity grid, district heating networks) and with non-energy services (e.g. mobility). This will allow buildings to play an active role in the energy system integration.

Proposals are expected to address all of the following:

- Develop new or upgrade existing building-to-grid integration solutions and demonstrate them in real-life pilots. The developed solutions should provide a user-friendly interface for building users and other interested stakeholders (e.g. facility managers, portfolio managers, aggregators) that allow them increased control over the use of their buildings' energy services and contracts (consumption, production, storage, flexibility).

- Enhance interoperability between buildings and grids for electricity and other energy carriers (e.g. district heating networks, hydrogen, etc.).

- Enhance synergies between on-site energy storage (e.g. home batteries, e-vehicles, etc.) and on-site renewable energy sources.

- Explore solutions for facilitating data exchange between buildings and other grid actors (such as ESCOs, aggregators, DSOs, etc.).

- Develop and pilot innovative and competitive energy balancing, storage and generation services in buildings, while maximising building users' and occupants' comfort and satisfaction.

- Demonstrate economic viability of the proposed solutions and business models for consumers and the economic actors involved.

Projects should build on the results from relevant past and on-going projects, in particular those that seek to upgrade smartness of existing buildings relying on legacy equipment (LC-SC3-B4E-3-2020).

To ensure interoperability and integration into the grid, projects should make use of operational end-to-end architectures, digital platforms and other data exchange infrastructure for the energy system being developed under ongoing Horizon 2020, Horizon Europe as well as under other EU programs such as the Digital Europe Program, when addressing communication and data exchange between inverters and other components, other appliances and the electricity network.

The selected projects are expected to contribute to relevant BRIDGE[63] activities.

D4-1-16. Thermal management and energy optimisation of high energy demand IT systems equipment in tertiary buildings

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Technology Readiness Level	4-5

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Better understanding of the challenges in thermal management of high-energy demand IT systems equipment in facility rooms inside tertiary buildings.
- Increased knowledge regarding solutions in the tertiary buildings case from transfer of relevant knowledge from other application field/sectors.
- Improved open access to the relevant and useful knowledge and information for the IT sector.
- Increased awareness of the most common specific use cases in tertiary buildings in Europe that could benefit from cost-effective and optimised thermal management and energy efficiency measures (solutions, practices, strategies, etc.), including solutions recovering and valorising of excess heat among others.
- Increased consensus amongst key actors regarding metrics, indicators, reporting, trends, monitoring and verification (M&V) schemes, methodologies & best practices to achieve best/optimal efficiencies through the design, commissioning, operation, management and decommissioning of IT systems equipment.

[63] h2020-bridge.eu

- Improved insight for future standardisation needs in relevant areas of influence (e.g. procurement, product design, manufacturing, services, cooling equipment, control equipment, buildings energy performance, operation, management, among others.) in order to facilitate further improvements and efficiencies in the relevant areas.

Scope: Energy consumption of IT systems equipment (e.g. server racks, server rooms) inside buildings is following a significant growth due to several factors. These factors include the increasing number of installed sensors and IoT devices, which feeds the need for big data handling and the increasing demand for more powerful and advanced equipment. Various voluntary and regulatory instruments have been implemented in the past years to try to mitigate the environmental footprint of a specific equipment/device or systems in isolation. However, often these instruments do not take into account real life performance, potential inefficiencies or synergies with other systems, operation under real life set-up and control conditions, or other constraints such as those from the building energy management practices, building automation and control systems, local regulations or rules. Moreover, there is potential to improve the self-assessment and self-optimisation functionalities at all levels.

Proposals are expected to address all of the following:

- Validate and improve awareness of the cost-effectiveness and value proposition of the best/optimal thermal management and energy efficiency measures (solutions, practices, strategies, etc.) and strategies for thermal management of high energy-demand IT systems equipment in facility rooms inside tertiary buildings.
- Improve the self-assessment and self-optimisation tools/functionalities of IT systems equipment inside rooms of tertiary buildings.
- Facilitate open access to latest information, trends and knowledge to all players involved.
- Promote the best/optimal measures/strategies.
- Identify needs for future regulation or standardization developments.

D4-1-17. Innovative solutions for cost-effective decarbonisation of buildings through electrification

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	6-8

Expected Outcome: Project results shall contribute to all of the following expected outcomes:

- Decarbonisation of building heating/cooling demand by means of electrification.
- Increased use of locally generated renewable energy and local energy storage.
- Enhanced buildings energy performance and (smart) energy management.
- Cost-effective and commercially available solutions for electrification of building thermal energy demand.
- Enhanced building contribution to power grid stability by offering energy flexibility services.

Scope: In line with EU priorities for buildings and the energy system, to develop and demonstrate highly cost-efficient, integrated and replicable solutions for decarbonising the thermal energy demand of buildings (i.e. heating/cooling) by means of electrification, taking as well into account the energy efficiency first principle.

Proposals are expected to address all of the following:

- Develop and demonstrate innovative and integrated solutions for electrification of the thermal energy demand of buildings (e.g. heat pumps, renewables and storage) with high replication potential across Europe.
- Ensure the solutions developed:
  - include innovative, smart control techniques optimising the heating/cooling systems performance and efficiency based on all relevant parameters, for example, dynamic electricity price (present and future forecast), weather (present temperature and solar radiation, and future forecast, resilience against extreme weather events), thermal comfort, status of charge of electrochemical and/or thermal storage etc.
  - include interoperable interfaces and rely on standards allowing to collect and store information on their operation, and communicating with other systems (e.g. building energy management systems or building automation and control

systems), for autonomous or remote inspection of systems (state, performance and failures).

- allow to increase the use of locally generated (on-site [64] and nearby [65]) renewable energy (solar thermal, PV, geothermal, excess heat, etc.) and storage (thermal or electrochemical), while offering energy flexibility to contribute to power grid stability.

- minimise life cycle environmental impact and improve circularity (reparability, modular design for selective replacement and upgrade, recyclability of materials, use of thermal cycle fluids with low global warming potential), while maintaining/enhancing their performance.

- are cost-effective (purchase, installation, operation and maintenance).

- are highly replicable, for new buildings and for renovation of residential buildings (individual dwellings, single apartments or flats), e.g. for the direct replacement of fossil-fuel boilers.

- Demonstrate the solutions developed in at least three real-life new construction and renovation projects, of which one at least is the renovation of a residential building (multifamily building or individual houses).

- Ensure that the demonstration:

  - covers at least three countries with diverse climatic conditions;

  - Involves local and regional values chains, in particular SMEs, based on participatory approaches to increase innovation acceptance;

  - Lead to clear and, where relevant, quantified and measurable indicators on the results achieved.

- Deliver guidance and recommendations for practitioners, and define and implement ambitious dissemination actions, to promote the approaches demonstrated and support their replication.

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[64] 'on-site' means the premises and the land on which the building is located and the building itself.

[65] 'energy from renewable sources produced nearby' means energy from renewable sources produced within a local or district level perimeter of the building, which fulfils all the following conditions: (a) it can only be distributed and used within that local and district level perimeter through a dedicated distribution network; (b) it allows for the calculation of a specific primary energy factor valid only for the energy from renewable sources produced within that local or district level perimeter; and (c) it can be used on-site of the building through a dedicated connection to the energy production source, that dedicated connection requiring specific equipment for the safe supply and metering of energy for self-use of the building.

Industry

D4-2-1. Alternative heating systems for efficient, flexible and electrified heat generation in industry (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all the following expected outcomes, except where options are specified:

- Alternative heating systems for electrified and efficient heat generation in industry, that create the possibility for new, decarbonised and flexible processes, maximising CO2 emission reduction compared to present state-of-the-art, demonstrated by LCA or similar studies (assuming decarbonised electricity use);
- *Optionally: adapt/rethink the process to take full advantage of alternative heating technology*
- Environmental and technical performances and economic viability of novel heating technologies demonstrated and validated in industrial processes;
- Better awareness of the challenges and benefits of alternative heating systems in the relevant industrial sectors.

Scope: Alternative forms of energy such as for example ultrasound, microwaves, plasma, light… are unconventional and contactless heat sources, that create the possibility of new, efficient and flexible processes, in that they are applied exactly where they are needed and with shortened reaction times. They are key enablers for switching processes from fossil energy to renewable or low-carbon energy sources, and can contribute to increasing their energy efficiency.

They provide higher production flexibility, allowing variable throughputs to better follow market demand and enabling leaner production paradigms (e.g. decreased stock, production on demand), as well as flexibility for the electricity grid via demand response. Furthermore, such technologies are suitable for downscaling, which can be an advantage in some cases (e.g. local waste or biomass feedstock processing).

Optionally, the scope can be extended to the adaptation or rethinking of the process, to take full advantage of alternative heating technology.

Note: the electrification of furnaces to heat large volumes at very high temperatures is not in the scope of this topic, because it is covered in Cluster4 work programme.

Further research and upscaling work is necessary to demonstrate their potential to be deployed on an industrial scale.

In order to reach this goal all the following development areas need to be covered:

- Cost effective and improved designs for at least two alternative heat sources technologies.
- Integration and demonstration of the system at pilot scale of at least one alternative heat source technology in at least on industrial process; demonstrate the financial viability and develop a business case.
- Make a preliminary estimation of the future equipment cost for at least one alternative heat source technology, in a total of at least three industrial applications (including the demonstrated application), to evaluate their economic potential.
- Make an analysis of the potential industrial deployment and related benefits (technical, economic, climatic, environmental) of at least one alternative heat source technology in three industrial sectors, in the EU and (if data are available) in the Associated States and, by extrapolation, at global level. Define an exploitation strategy.
- Disseminate the benefits, notably (but not only) to the communities of the relevant Horizon Europe private-public partnerships.

D4-2-2. Integration of renewable heat or waste heat in heat-to-cold conversion systems to generate cold for industrial processes (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all the following expected outcomes, except where options are mentioned:

- Integration of renewable thermal energy sources or industrial waste heat into more energy-, emissions-, cost- and space-efficient conversion systems generating cold for several industrial sectors and processes, maximising CO2 emission reduction compared to present state-of-the-art.
- Optionally: integration of heat storage, of renewable electrical energy sources.
- *Optionally: combined generation of heat and cold for industrial processes*

Scope: Increasing the efficiency of the cooling systems and reducing costs, coupling the cooling systems with renewable energy sources, and harnessing available industrial waste heat (including from data centres), can contribute to reduce the environmental impact and make the industrial sectors more competitive.

In order to reach this goal all the following development areas need to be covered:

- Identify the target industrial processes which would benefit from the integrated cooling systems; assess the impacts on these processes in terms of energy savings and GHG and air pollutant emissions reductions in the EU (and Associated States, if data are available), so as to maximise the impact and coverage of the most promising solutions in the subsequent optimisation and demonstration steps. A preliminary assessment is expected at proposal stage.
- Improve the refrigeration system efficiency and environmental friendliness, for example: improve the control system and operating strategies; develop internal recoveries for refrigeration plants (e.g. vapour compression plants); advanced and environment friendly organic fluids and novel heat exchangers for refrigeration systems (e.g. absorption systems); combine the generation and use of both heat and cold.
- Integrate and demonstrate the refrigeration system in an industrial application in at least one industrial sector, including the mandatory integration of on-site or near-by solar thermal or geothermal plants with minimisation of the space needed. Optionally also: harvesting of industrial waste heat; thermal storage; cold transportation; integration of renewable electrical energy sources, with possible electrical demand flexibility for contributing to the stabilisation of the electrical grid.

- Identify the potential barriers to the deployment of the integrated cooling solutions due to thermal renewables variability, investigating notably other mitigation alternatives than gas-fired backups, such as insurance mechanisms to alleviate the financial risk for the company. Identify non-technical barriers due to the local regulatory framework in the EU Member States and Associated Countries.
- Make an analysis of the potential industrial applications and related benefits (technical, economic, climatic, environmental) of integrated cooling solutions in at least four different industrial processes, in the EU and (if data are available) in the Associated States and, by extrapolation, at global level. Define an exploitation strategy.
- Disseminate the technical and economic benefits, notably (but not only) to the communities of the relevant Horizon Europe private-public partnerships.

Destination – Clean and competitive solutions for all transport modes

This Destination addresses activities that improve the climate and environmental footprint, as well as competitiveness, of different transport modes.

The transport sector is responsible for 23% of CO_2 emissions and remains dependent on oil for 92% of its energy demand. While there has been significant technological progress over past decades, projected GHG emissions are not in line with the objectives of the Paris Agreement due to the expected increase in transport demand. Intensified research and innovation activities are therefore needed, across all transport modes and in line with societal needs and preferences, in order for the EU to reach its policy goals towards a net-zero greenhouse gas emissions by 2050 and to reduce significantly air pollutants.

The areas of rail and air traffic management will be addressed through dedicated Institutional European Partnerships and are therefore not included in this document.

This Destination contributes to the following Strategic Plan's **Key Strategic Orientations (KSO)**:

- *C: Making Europe the first digitally enabled circular, climate-neutral and sustainable economy through the transformation of its mobility, energy, construction and production systems;*
- *A: Promoting an open strategic autonomy*[66] *by leading the development of key digital, enabling and emerging technologies, sectors and value chains to accelerate and steer the digital and green transitions through human-centred technologies and innovations.*

It covers the following **impact areas**:

- Industrial leadership in key and emerging technologies that work for people;
- Smart and sustainable transport.

The **expected impact**, in line with the Strategic Plan, is to contribute *"Towards climate-neutral and environmental friendly mobility through clean solutions across all transport modes while increasing global competitiveness of the EU transport sector*", notably through:

a. Transforming **road transport to zero-emission mobility** through a world-class European research and innovation and industrial system, ensuring that Europe remains world leader in innovation, production and services in relation to road transport (more detailed information below).

b. Accelerating the reduction of all **aviation** impacts and emissions (CO_2 and non-CO_2, including manufacturing and end-of-life, noise), developing aircraft technologies for

[66] *'Open strategic autonomy' refers to the term 'strategic autonomy while preserving an open economy', as reflected in the conclusions of the European Council 1 – 2 October 2020.*

deep reduction of greenhouse gas emissions, and maintaining European aero-industry's global leadership position (more detailed information below).

c. Accelerate the development and prepare the deployment of climate neutral and clean solutions in the inland and marine shipping sector, reduce its environmental impact (on biodiversity, noise, pollution and waste management), improve its system efficiency, leverage digital and EU satellite-navigation solutions and contribute to the competitiveness of the European **waterborne sector** (more detailed information below).

d. Devising more effective ways for **reducing emissions and their impacts** through improved scientific knowledge (more detailed information below).

Zero-emission road transport

Main expected impacts:

1. Affordable, user-friendly charging infrastructure concepts and technologies that are easy to deploy with a wide coverage of of urban spaces and of the road network and include vehicle-grid-interactions, ready for mass electrification of passenger and freight road transport.

2. Accelerated uptake of affordable, user-centric solutions for optimised energy efficiency and energy flexibility (vehicles and services).

3. Effective design, assessment and deployment of innovative zero-emission solutions for the clean road transport challenge.

4. Innovative demonstrations use cases for the integration of zero tailpipe emission vehicles, and infrastructure concepts for the road mobility of people and goods.

5. Increased user acceptance of zero tailpipe emission vehicles, improved air quality, a more circular economy and reduction of environmental impacts.

6. Support EU leadership in world transport markets at component, vehicle and transport system level, including related services.

Aviation

Main expected impacts:

1. Disruptive low TRL technologies that have potential to lead to 30% reduction in fuel burn and CO2, by 2035, between the existing aircraft in service and the next generation, compared to 12-15% in previous replacement cycles (when not explicitly defined, baselines refer to the best available aircraft of the same category with entry into service prior to year 2020).

2. Disruptive low TRL technologies that have potential to enter into service between 2035 and 2050, based on new energy carriers, hybrid-electric architectures, next generation of ultra-high efficient engines and systems, advanced aerostructures that

will enable new/optimised aircraft configurations and their cost-competitive industrialization.

3. New technologies for significantly lower local air-pollution and noise.
4. Increased understanding and analysis of mitigation options of aviation's non-CO2 climate impacts.
5. Accelerated uptake of sustainable aviation fuels in aviation, including the coordination with Member States and private initiatives.
6. Maintain global competitiveness and leadership of the European aeronautics ecosystem. Focus on selected breakthrough manufacturing and repair technologies that have high potential to lower the overall operating cost.
7. Further develop the EU policy-driven planning and assessment framework/toolbox towards a coherent R&I prioritization and timely development of technologies in all three pillars of Horizon Europe. Contribute to the mid-term Horizon Europe impact assessment of aviation research and innovation.

Waterborne transport

Main expected impacts:

1. Increased and early deployment of climate neutral fuels, and significant electrification of shipping, in particular intra-European transport connections.
2. Increased overall energy efficiency and use of renewable energies such as wind to drastically lower fuel consumption of vessels. This is increasingly important considering the likelihood of more expensive alternative fuels, where in some cases the waterborne sector will have to compete with other transport modes.
3. Enable the innovative port infrastructure (bunkering of alternative fuels and provision of electrical power) needed to achieve zero-emission waterborne transport (inland and maritime).
4. Enable clean, climate-neutral, and climate-resilient inland waterway vessels before 2030 helping a significant market take-up and a comprehensive green fleet renewal which will also help modal shift.
5. Strong technological and operational momentum towards achieving climate neutrality and the elimination of all harmful pollution to air and water.
6. Achieve the smart, efficient, secure and safe integration of maritime and inland shipping into logistic chains, facilitated by full digitization, automation, resilient and efficient connectivity.
7. Enable safe and efficient fully automated and connected shipping (maritime and inland).

8. Competitive European waterborne industries, supporting employment and reinforcing the position of the European maritime technology sector within global markets. Providing the advanced green and digital technologies which will support European jobs and growth.

Impact of transport on environment and human health

Main expected impacts:

1. The reduction of road vehicle polluting emissions (looking at both regulated, unregulated and emerging ones) from both existing and future automotive fleets in urban areas.
2. The better monitoring of the environmental performance and enforcement of regulation (detection of defeat devices, tampered anti-pollution systems, etc.) of fleets of transport vehicles, be it on road, airports and ports.
3. Substantially understand and provide solutions to reduce the overall environmental impact of transport (e.g.: as regards biodiversity, noise, pollution and waste) on human health and ecosystems.

Zero-emission road transport

D5-1-1 Static, smart, low-cost pervasive slow charging and bi-directional solutions compatible with the grid for EV mass deployment (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex B.

Expected outcome:

Projects are expected to contribute to all the following outcomes:

- Development and demonstration of innovative, efficient, not visually intrusive charging solutions for smart and bi-directional charging, removing barriers to EV user acceptance.
- Development of an analytical methodology (replicable at an EU-wide scale) to plan the mass deployment of public and private EV charging infrastructure[67], satisfying both concrete user needs (in particular for night charging of L, M1 and N1 vehicles and their opportunistic day charging) and grid possibilities.
- Development of related business models, including for less densely populated areas.
- Development of socio-cultural databases at city, regional and national level comprising daily charging habits, practices and ideas of different communities including their marginal groups
- Support to relevant activities for the establishment of common standards, protocols and digital services.

Scope:

Future charging infrastructure deployment should be ubiquitous, paralleling the growth of EV sales. Associated charging solutions should enable seamless processes that are easy and available at any time. The aim of this topic will be to improve smart charging of EVs as well as the efficiency of power supply to the grid, including a space-time-oriented prediction of the charging power demand.

Projects are expected to cover all the following aspects

- Optimise locations for on-street charging stations considering grid infrastructure and capacity, grid requirements for services and traffic needs including the stationary traffic patterns (charging on long- and short term parking spaces) to reduce the need for additional buffers stabilising the grid.
- Optimise the use of energy resources and infrastructures to cater not just for individual mobility usage (mostly at night) but also to integrate diurnal energy use by public transport, collective taxis, urban utility vehicles …
- Addressing the needs and requirements of users in socio-cultural contexts of different communities that incorporate daily habits, practices, ideas into the design and development of people-friendly public and private charging infrastructure, determining the most efficient charging solutions.

[67] Considering, where appropriate, deployment targets under the Alternative Fuels Infrastructure Regulation (AFIR) and Energy Performance of Buildings Directive (EPBD) proposals

- Statistical models of traffic vs. grid flows to predict and support power supply planning on a larger scale (e.g. at least regional).

- People centric Human Machine Interfaces (HMI) systems that support the interactions related to the ratio between location, power and price for prompt decision making or pre-allocation of charging stations in line with user charging preferences and vehicle state of charge, allowing charging point operators to predict power demand.

- Support and demonstration for V2X operation in residential and commercial environments[68], harbour or opportunistic charging types, motivating the people to charge especially during peak renewable power availability periods including the pre-allocation of charging points and promoting the development and use of interfaces with fit-for-purpose vehicle technology which can be fully preconditioned and set-up by the driver.

- Development of innovative optimisation functions exploiting real-time access to battery information such as state of health, state of charge, capacity and power set point, which shall be provided under non-discriminatory terms and free of charge to the owners or users of the batteries and the entities acting on their behalf, such as building energy system managers, mobility service providers and other electricity market participants.

D5-1-2 Integration and testing of electrical powertrains above 800V (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA/IA
Technology Readiness Level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex B.

[68] Operation shall be on non discriminatory terms between users and classes of users and allow the choice of the e-mobility service providers, so as to avoid consumers lock in with the single e-mobility service provider, affiliated to specific vehicle manufacturers

Expected outcome:

To achieve safer and higher-performing but more sustainable end products, project results are expected to contribute to most of the following expected outcomes:

- Increased affordability of EVs for broad mass markets, taken into account volume effects and cost optimized architectures for future markets, based on recent technological progress.
- Further range increases, faster charging and easier thermal management of the whole powertrain.
- Towards a holistic vehicle platform: development of physically and functionally highly integrated e-powertrain technologies.
- Highest efficiency and best fitting grid interaction during the whole vehicle operation (driving– from partial load to full acceleration condition usage, charging, stand-by time, scheduling of upcoming drives).
- Increased life time, reliability and availability of the powertrain.
- Improved application safety and robustness that contribute to a better user acceptance.
- Improved resource efficiency with better lifecycle impact and recycling capability ¬ contributing to a circular economy approach. A cost reduction of a minimum of 20% of power electronic modules and inverters for a given power shall be demonstrated (in comparison to the cost of the best current-generation or close to market components at proposal submission time).

Scope:

To evolve the next generation's electric vehicles, the power and application needs show an increase from board net HV voltage from 400V to 800V and above. Voltages > 800 volts may become standard in the next decade, but will have an impact on the overall architecture especially in terms of DC charging and efficiency for low power use. Thus, new challenges for the powertrain arise in the areas of the motor, battery, as well as in the development and integration of power semiconductors (e.g. SiC >800V). Overall, the main target is to achieve a highly functionally integrated, efficient, reliable and compact e-powertrain including intelligent control and diagnostics techniques.

To successfully address the expected outcomes in the constant drive to improve efficiency and performance while increasing affordability, following R&I actions need to be tackled:

System:

- Successful development and integration of >800V power-electronic components with new concepts for component miniaturization and modularity. Also, solutions that can transition rapidly from modular to integrated systems need to be identified, depending on demand and ecobalance.

- Significant advancements in efficiency (reduction of losses by 25%) and thermal performance (increased maximum operational temperature and higher thermal dissipation of power electronics), both parameters versus the state of the art of the targeted application; Large efficiencyy improvements should be targeted also in partial load condition.

- Using AI approaches to apply integrated control features or diagnostics techniques/ predictive maintenance.

- Increasing inverter power.

- Topologies adapted to advanced WBG semiconductors and new materials.

- Modular vehicle platforms: Aim is to come closer to a full integration of the three systems of the electric motor, the power electronics systems and the battery pack. (The integration can be mechanical, electrical or thermal.) For example, greater system integration need to be achieved in the areas of e-axles, DC charging functionality, multiple wheel drive (through the integration of near-wheel or in-wheel motor with other corner components), etc.

- Defining suitable testing and validation procedures on component, corner system, powertrain or vehicle level and demonstrating them on a suitable use case. Furthermore, common EU standards for system validations need to be defined.

- New powertrain designs with electrical safety mechanisms in case of unexpected events, e.g. collisions or other accidents.

Power Modules:

- A cost reduction of a minimum of 20% of power electronic modules and inverters for a given power shall be demonstrated (in comparison to the cost of the best current-generation or close to market components at proposal submission time).

- Small-sized power modules for greater design flexibility while optimizing costs.

- Power modules ‘ready for integration’ at the best system fitting position (e.g. e-motor or battery).

- Consider the optimal trade-offs between proprietary power modules vs. standardization.

- Packaging solutions e.g., substrates, molding epoxy, electrical interconnections, adapted for high-frequency switching, frequent thermal cycling, elevated temperatures etc.

- Higher power density.
- Heat spreading technologies for short power pulses/ Heat dissipation approaches for long duration pulses, long acceleration phases.
- The development of the needed semiconductors shall not be included in the funding and suppliers shall guarantee in writing the availability of their latest prototypes of the technology proposed for integration in the project, in particular when semiconductor development has been funded by ECSEL and KDT JUs.

D5-1-3 User-centric design and operation of ZEV for optimized energy efficiency (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA/IA
Technology Readiness Level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex B.

Expected outcome:

In the coming years, user-centric design, predictive control and artificial intelligence will offer significant opportunities to improve both the design and the operation of zero emission vehicles (ZEV) to make them more affordable and offer an even more attractive driving experience. This includes particularly the potential from thermal energy management, ranging from the system and components to the vehicle interior.

Projects are expected to contribute to all the following outcomes:

- Accelerated uptake of user-centric solutions for affordable, optimized energy efficient vehicles through innovative concepts and optimised system and component sizing.
- Component sizing matched to the reliability requirements to reduce product costs by at least 5% at vehicle level.

- Reduced development time by 30% through advanced design support and control algorithms in ZEV systems and powertrains.

Scope:

Project scope shall consider both the operational perspective (user behaviour, preferences, route planning, infrastructure, weather conditions, etc.) and the technological perspective addressing new approaches based on artificial intelligence and the potential of connectivity. Projects should address all of the following aspects:

- Development of optimised heating/cooling and demisting concepts and components capable of greatly reducing energy consumption to perform these functions, particularly when coupled with smart controls.
- Development of methods to automatically pre-condition vehicles prior to trips and enabling self-adjusting control strategies during operation. This includes vehicle systems, powertrain electric and thermal management based on AI supported learning/analysis of ZEV user driving patterns, travel route conditions and weather conditions to maximise the range benefit.
- Data driven decision making enabling optimal interior design fulfilling perceived driver needs, as well as, e.g., AI supported adjustment of operation and controls of the system including of powertrain and auxiliary, components and their thermal state as well as cabin comfort to avoid peak loads and ensure minimum energy consumption.
- Identify the optimal system layout and possible interactions through multiple scalable digital twins (thermal modelling of components, vehicle model, powertrain model, driver model).
- New modular interoperable systems to enable the use of real-life data from vehicle fleet operation to automatically (pre-)adjust control parameters to minimize engineering effort in calibration stage as well as to maintain optimal performance over vehicle life-time, e.g., to enable continuous learning of the applied AI and adaptability to work on-board in “real-time” control systems. However, such systems should not be proprietary and access of third parties for services such as repair and maintenance should be secured.

D5-1-4. Advanced battery system integration for next generation vehicles (2024)

Specific conditions

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA/IA
Technology Readiness Level	Activities are expected to achieve TRL 5-7 by the end of the project – see General Annex B.

Expected outcome:

Projects are expected to contribute to all the following outcomes:

- Novel and innovative approaches to battery integration concepts into vehicle structure for next generation cells, including modular systems capable of temporary expansion for long trips in small vehicles.
- Weight and space saving.
- Safe and sustainable integration of batteries in vehicles.
- Improvement of the fast charging capabilities.
- Overall improved cost efficiency.
- Enhanced overall battery system efficiency (high energy and power densities for the whole battery pack).
- Smart thermal management systems, including synergies with passenger comfort.
- Physical/mechanical integration of battery capacity in various locations in the vehicle structure considering functionality and cost prospective in the production and recycling processes.

Scope:

In order to reduce the overall cost of electric vehicles modularity, scalability and the development of strategies for their implementation will become increasingly important in the future.

With the expected introduction of new cell technologies, specific choices for connections, cooling system concepts and materials for housing will play a crucial role in the battery performance improvements. The development and integration of structural, thermal and mechanical aspects (at different levels of modularity or integration) will need to be improved, while exploiting the intrinsic advantages of the new type of cells.

- Customised vs. modular battery system concepts
- Development of the technical communication channel for the access and exchange of relevant data types from the battery management system, such as state of charge (SoC), state of health (SoH), temperature (T) or voltage (V) are essential to ensure efficient and secure recharging processes. Compliance and testing of existing standards for vehicle-infrastructure communication[69] shall be ensured.
- Smart thermal management systems for both heating and cooling, with smart interfaces to the vehicle systems, including energy-efficient preconditioning, using internal or external energy facilities whilst charging, will contribute to further improvements in the overall battery system efficiency and optimizing the overall battery system.
- Digital twin of thermal behaviour of EV and battery for optimal chemistry / energy management and safety assessment of batteries.
- Novel cooling system concepts ensuring minimal impact on system mass and costs, especially taking into account the thermal and electrical interfaces of cell geometries (e.g. pouch, prismatic or cylindrical).
- Recyclability aspects should be considered.
- Projects should take into account the proposal for the Renewable Energy Directive COM(2021) 557 of 14 July 2021 final real-time access to basic battery information such as state of health, state of charge, capacity and power set point should be provided under non-discriminatory terms and free of charge to the owners or users of the batteries and the entities acting on their behalf, such as building energy system managers, mobility service providers and other electricity market participants.

D5-1-4 B - Innovative battery management systems for next generation vehicles (2Zero & Batteries Partnership) (2023)

Specific conditions

69 Specifically, ISO 15118, OCPP, OCPI, and if already adopted IEC 63110 and IEC 63119

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL XX by the end of the project – see General Annex B.

Expected outcomes

Projects are expected to contribute to all of the following outcomes:

- A simplified, efficient and interoperable battery management system including a reduction of parts and cost (optionally by using cloud-based battery status calculation with adequate consideration of security aspects if a low climate impact can be proven), including easy-to-use data for second-life-applications.
- Improved and optimized monitoring and predictive diagnostics for a more accurate reliable and efficient battery management maintenance (data-driven diagnostics, on-the-fly software updates and firmware replacements, self-testing and on-board diagnostics).
- Generally improved battery performance and battery pack volumetric density (by 10% or more), fast charging control, safety and prolongation of battery life-time (by at least 30%) by considering algorithms for cell level state of health, cell aging prediction and battery state estimation, including also the integration of smart sensor systems.
- Improved control of battery operating conditions and determination of key state estimators (e.g., State of Health, State of Power, State of Safety, SoE) to increase accuracy and to improve the early warning capability for performance, reliability, safety, and lifetime issues on all battery system levels.
- New simulation tools and test methods for faster development, validation and integration of the battery pack, considering assembly design (reducing cabling for the external voltage detection communication function) and realizing a reduction of testing time by 30% (collection of battery characteristics for SoX algorithm optimization using less calibration SoX algorithm).
- Enhanced communication between battery and vehicle control unit for a more efficient battery operation by synchronizing ECUs of the BMS and the BEV.

Scope:

Advances in the design of an efficient battery management system (BMS) are of high significance when it comes to the integration of batteries in electric vehicles and the general improvement of battery performance. In order to provide the vehicle control unit with detailed information on battery operation, thereby achieving the longest possible lifetime, battery monitoring and diagnostics are vital system functions. New concepts will have to include predictive SoX diagnostics (based on sensing at cell level) to accurately predict the end-of-life, as well as high connectivity and data storage to optimize the life and general use of the BEV.

Compact, high energy density batteries as they are used in road transport applications are complex, potentially dangerous and expensive. To a rather significant extent, the high cost is driven by sizing margins, which are imposed due to lack of information about the overall state of the battery (during operation and at the end of the first life). The basic understanding of the battery must therefore be improved and combined with secure, real-time and databased battery management to reduce these margins in a controlled manner and to ensure optimized, safe utilization during all modes of operation and accurate classification for a second life.

The identification of right-sizing rules and definition of suitable profiles for charging (especially fast charging) considering both safety and user requirements plays an important role, as well.

The advanced use of physics-based, data-driven or hybrid models in general, considering for example Artificial Intelligence (AI) with machine learning algorithms, model training and self-adaptive functions will lead to scalable, fully automatized and optimized solutions in terms of efficiency and costs.

With regard to the integration of the EVs to the electricity grid and new services such as for the smart charging and aggregation, the RI should take into account the proposal of for the Renewable Energy Directive COM(2021) 557 of 14 July 2021 final real-time access to basic battery information such as state of health, state of charge, capacity and power set point should be provided under non-discriminatory terms and free of charge to the owners or users of the batteries and the entities acting on their behalf, such as building energy system managers, mobility service providers and other electricity market participants.

D5-1-5 User-centred and co-designed shared, automated and zero-emission mobility systems and services for people and goods (2Zero, CCAM and Cities' Mission) (2023)

Specific conditions

Expected EU contribution per project	The Commission estimates that an EU contribution of [around EUR XX million / between XX-YY million] would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex B.

Expected outcome:

Project results are expected to contribute to ALL the following outcomes:

- Contribution to city-led mobility strategies aiming for climate neutrality of cities by 2030.
- Roll-out of user and market-based solutions for seamless integration of shared, automated and zero emission mobility solutions and infrastructures in a citywide transport system.
- Co-design mechanisms among local authorities, users and automated and zero-emission mobility systems providers are established to increase the innovation capacity of local/regional administrations and accelerate the take-up of innovative smart and zero emission mobility solutions.
- Viable business cases both for passengers and goods that could lead to private and/or public investments and replication among the cities participating in the Cities Mission.
- Better use of infrastructure for transport through connectivity, contributing to improved mobility services for passengers and freight and better use of public spaces.
- Mobility systems and services for people and goods contributing to:
    - Elimination of harmful emissions by xx%;
    - Reduced congestion, more reliable, predictive travel times and more efficient transport operations;
    - Increased safety and zero road deaths by 2050;
    - Improved inclusiveness, especially by facilitating affordable access to mobility for all users.

Scope:

Urban mobility for passengers and goods is one of the most critical sectors that cities need to address on their way to climate neutrality. To ensure the transition of the entire urban system to climate neutrality, cities, users (including passengers and freight transport and logistic operators) and automated and zero-emission mobility systems providers (in CCAM and 2ZERO) will have to work together to integrate new mobility technologies and solutions in their planning and actions. They should also define and create the framework conditions to roll out such innovative smart mobility solutions to fully exploit the potential of electric, connected, cooperative, automated and shared road transport, by combining and integrating their developed innovative technologies in novel systemic solutions for people mobility and goods transport.

As this requires coordinated innovations in vehicles, infrastructure and services affecting citizens, planners, operators and businesses alike, the solutions are to be co-designed, tested and evaluated in relevant environments and use cases. This topic will demonstrate the synergetic potentials of collaborative research on e.g. power grid integration, vehicle cooperation and road traffic management. As part of the European Mission on Smart and Climate-Neutral Cities, this topic will develop co-design mechanisms among local authorities, users and automated and zero-emission mobility systems providers to generate practices and define solutions that can be replicated and scaled up to other cities.

These co-design mechanisms shall be applied to test shared, automated and zero-emission mobility systems and services for people and goods or both in urban and suburban areas in large-scale demonstration projects, using purpose-designed vehicles (rather than derived from current designs) optimising their use and that of related infrastructures (physical, digital, charging). Sub-urban areas must be included in proposed solutions, so as to widen the pool of possible users of these solutions, services and systems.

Demonstrations must aim at developing user oriented and climate neutral mobility solutions as part of an integrated sustainable urban mobility plan (SUMP) at local or regional level. Systems and services that will be tested will take full account of existing urban ecosystems and (future) policy/regulatory needs. Projects should be user focused targeting implementation of tests at city level to ensure buy-in, acceptance and thus a seamless integration of mobility solutions and infrastructure in a citywide transport system. Particular attention should be given to last-mile mobility solutions complementing existing public transport / freight delivery services. Projects will feed back real-world challenges and opportunities to the 2Zero and CCAM partnerships.

Projects might also support the development of skills on urban mobility and logistics planning within the local authorities and co-creation with private stakeholders (e.g. as per SUMP and SULP guidelines).

D5-1-6. Frugal zero-emissions vehicles concepts for the urban transport challenge (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex B.

<u>Expected outcome:</u>

Projects should deliver solutions tailorable for specific usage models and particular market factors in order to contribute to all the following impacts:

- Accelerated global uptake of affordable, user and mission centric solutions tailorable for specific usage models and particular market factors both in advanced and emerging markets.
- Effective design, assessment and deployment of innovative zero-emission solutions (L, M1 and M2 categories) for the clean urban transport challenge.
- Higher sustainability and minimized cost by leveraging scale economies but still offering flexible variations through modularity.
- Ensured ease of use in targeted urban and sub-urban areas that accounts for traffic and parking conditions as well as for battery charging/swapping points availability.
- Reduction of environmental impacts by accelerating the application of circular economy principles, in particular design-for-reuse for components and systems as well as the usage of eco-sustainable materials.

<u>Scope:</u>

Urban spaces will be changing in the future. There will be a massive shift from the parking-lot culture in the city to recovery of living spaces as well as increasing intelligence in the urban spaces. Both will have a strong impact on individual means of mobility. New vehicle concepts that harmonize with these new developments, but also achieve widespread user-acceptance will be needed. Platform concepts with sufficient variability will be able to meet the needs of both advanced and emerging countries.

New designs, shapes, architectures and functionalities capable of delivering mass-market capable frugal versions for emerging markets and versions in the EU and advanced markets with a single, generic platform, including swappable and interoperable battery systems (for L-category) should be covered.

Project scope shall address vehicles that are specifically better-suited for operation (in appropriate versions) in future urban spaces both in emerging as well as established markets. R&I actions should focus on:

- Systematic and thorough analysis of the development (e.g. from traffic control, charging infrastructure and parking, to information and communication technologies) and user centric needs, due to future evolution of urban areas representative for both emerging and established market use cases.
- Development and validation of at least two variations of the modular and scalable vehicle (i.e. basic low-cost version and higher value version based on the same adaptable platform with high-production volume potential). For L-category vehicles this should include the option of swappable and interoperable standard battery systems (across world regions, for larger economies of scale) which can optionally be used for light M-category vehicles, for instance for range extension or emergency use.
- Validation with real zero emissions vehicle(s) and related battery solutions testing, demonstrating the developed functions, in particular the capabilities of the proposed architecture in terms of payload, charging requirements etc.
- Confirmation of user acceptance in both emerging markets and established markets according to the purpose of the particular version.
- Assess the potential impact in terms of emissions reduction considering the potential scale-up opportunities of the addressed use cases, prioritizing higher impact use cases.
- Taking into consideration future development pathways for urban public, semi-public, private charging infrastructure adapted for such future urban vehicle concepts, in particular in the developing countries where such infrastructure is currently non-existent.
- Projects should deliver digital twin models of the demonstrator vehicles, such that the impact of the innovations towards the overall objectives of the 2Zero partnership might be determined prior to the completion of the project. Data that are produced as output from a 'digital twin' should be FAIR, and deposition in relevant repositories should be encouraged.

Topic open to international collaboration, in particular in emerging economies.

D5-1-7. Circular economy approaches for zero emission vehicles (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA/IA
Technology Readiness Level	Activities are expected to achieve TRL 6 by the end of the project – see General Annex B.

Expected outcome:

Implementing a consistent circularity along the BEV value chains and life-cycle (in particular for mass produced Light Duty vehicles but with potential learning for other types of vehicle) will be a significant factor to reach the goals defined in the European Green Deal. As such, projects are expected to contribute to the following outcomes:

- Increasing the degree of circularity of BEVs, thus reducing their environmental footprint over the full life-cycle and contributing to the targeted 55% reduction of greenhouse gas emissions in 2030.
- Increasing the awareness and acceptance of circular economy and LCA based design of innovative zero-emission solutions for the clean road transport challenge.
- Contributing to a harmonised way to measure the circularity of the economy in the automotive industry.
- Demonstrating the potential of these actions by delivering a completely circular car prototype.
- Accelerating the transformation of Europe towards being the first digitally enabled, circular, climate-neutral and sustainable economy.
- Increasing the sovereignty of Europe through reducing the dependency on critical raw materials via the consistent recovery and use of secondary materials.

- Contributing to Europe's world leadership in automotive innovation, production and services through increasing skills with circular economy techniques and accelerating the uptake of innovative CE-based solutions for BEV.

Scope:

The objective will be to demonstrate the feasibility of circular economy (CE) and net-zero approaches for the battery electric vehicle (BEV) value chain over its full lifetime (cradle to cradle). Aiming at minimal energy use and minimal emission, as well as a high degree of circularity (close to 100%), the proposed activities should focus on the vehicle production (design, manufacturing and assembly), maintenance, repair and End-of-Life (EoL). Additionally, LCA-based vehicle concepts, their related resource and energy efficient manufacturing and CE consistent EoL strategies should be shown. A digital twin of the demonstrator should be used to assess various scenarios, including the use of recycled or bio-based materials.

Proposals shall address all the following BEV-related research activities:

- Elaborating a consistent circularity strategy, from production (design, manufacturing and assembly) until End-of-Life and demonstrating its feasibility on vehicle level over the full life cycle. This includes a re-design of components for circularity.
- Enhancing digital tools enabling a higher degree of circularity along the automotive value chain, e. g. for design and development, manufacturing or to track materials, their use und EoL. Production, maintenance, and repair technologies, as well as EoL strategies will be developed or adapted to ensure a higher degree of circularity compared to existing practices in the passenger car industry.
- Deriving a concept for measuring and assessing the circularity of BEV solutions as well as for ensuring a sufficient exchange of information along the automotive supply chain applying FAIR principles.
- Concepts for training and increasing the required skills in the automotive industry regarding CE.

The research activities shall apply the findings of vehicle level LCA methodology developed by the CSA funded under HORIZON-CL5-2021-D5-01-04 as far as they are available.

D5-1-8. Integrated flexible multipoint megawatt charging systems for electric truck mass deployment (2024)

Specific conditions

Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Technology Readiness Level	Activities are expected to achieve TRL 6 by the end of the project – see General Annex B.

Expected outcome:

Project results should contribute to all outcomes below:

- Improved designs, architectures and models of inter-operable multipoint megawatt charging systems for future mass deployment of heady duty trucks and concepts for managing their grid impact.
- More energy efficient charging sub-systems and improved power and thermal management for mega-charging hubs.
- Integrated and flexible interaction control and energy management between on-board and off-board charging-related components and any or all of local grid demand flexibility providers, renewable generation and energy storage systems, including interface specifications for European harmonisation.
- Improved modeling of the optimal geographical locations for large-scale megawatt charging hubs for Heavy and Medium Duty Vehicles and multiplexed Light Duty passenger and commercial Vehicles usage at peak times in consideration of locally available energy grid capacity.
- Tools and services for planning, operation, availability and reliability of the overall megawatt charging hub, from both energy provider and users' perspetives.

Scope:

Next generation battery electric vehicles need to be more energy efficient and affordable, which means to keep battery size to the practical minimum. Megawatt charging is then required to meet the demand for long operational range with even shorter charging times, which put extra strain on battery lifetime and reliability. Megawatt charging will require improved on-board sub-systems and innovative solutions to take next step in complete vehicle development. Specific Megawatt level charging technologies and on board charging subsystems developed in the 2022 long range truck topic will need to be deployed in significant numbers to cover the TEN-T network while managing the grid issues that will emerge when such concentrated high power demand. At the same time these charging hubs will be usable for lighter vehicles during peak times, when normally demand for heavy duty vehicles is lower.

Typical demands in significant geographical areas shall be presented. Opportunities for sharing and balancing power supply within studied areas and locations and with nearby depots for overnight charging, public transport, car-parking, construction machines etc. should be considered. Input from European/Member state maps with aggregated charging demands and expected high power charging station localisations is also expected.

Particular attention should be paid to the real needs of end users, including optimised infrastructure location, its reversed impact on the traffic, ease of use and interoperable protocols that do not hinder universal use across different countries. The developed tools should have the capability to map out the optimal locations for a fast and high-power charging infrastructure (service centers, depot, logistics hubs and on highways, also considering the permitting process), offering planning options to the developers of the targeted infrastructure. For optimization of the over-all system use, services and tools should be developed keeping into account on-board BEV system characteristics.

Demonstrations of integrated flexible megawatt on-board systems and off-board charging stations for HDV/MDV and also open to LDV/LCV for maximum outputs of ≥1 MW.

International (US) collaboration in particular regarding interface specification

D5-1-9. Advanced digital development tools to accelerate the development of software defined vehicles that enable zero-emission mobility (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA/IA
Technology Readiness Level	Activities are expected to achieve TRL 4-6 by the end of the project – see General Annex B.

Expected outcome:

Advanced digital tools can enable the mobility industry to efficiently develop and operate software-defined zero emission vehicles (ZEV) that are key for achieving sustainable mobility solutions. Core functions of the electric powertrain or vehicle dynamics are primarily enabled and controlled via software. Function updates are at the fingertip of the end-users to offer maximum customer benefits and satisfaction. Such next generation modelling and simulation tools & methods empowering e.g., software-driven development, automated engineering as well as credible simulation pave the way to make mobility safer, more sustainable and more comfortable in a new way.

Project are expected to contribute to the following **outcomes:**

- Design and validate digital tools for the vehicle industry for enabling best possible combination of digital development and digital operation for innovative zero-emission solutions and to ensure performance, security, safety and reliability by design.
- Increase speed of innovation by optimising the utilization of data (engineering data, operational data etc.) in an effective and efficient way (synthesis and utilization of data).
- Contribute to the development of solutions for reliable 'virtual' decision-making based on digital twins and for enhancement of the credibility of simulations based on process and artefact quality measures, as well as KPI-driven quality assurance and quality traceability.
- Method and tools for reliable modeling and simulation of total vehicle systems including its environment.
- Significantly enhance the capabilities in design, development and application of "software-defined" ZEV and thus strengthening the competitiveness of the European automotive industry.

Scope:

The data driven development of software-defined functions and systems of ZEV (e.g. in context of battery and e-motor control, predictive eco-driving functions or control of vehicle dynamics, safety as well as comfort) requires the use of improved tools across domains (e.g. mechanical, dynamic, electrical, and acoustical) and scales (from component to vehicle to vehicle in a mobility scenario) as well as a deep understanding of the vehicle operation in real life.

However, the current development and design framework does not allow such complex software-defined functions and systems to be addressed in an integrated manner, resulting often in solutions optimised for a specific operating point that is only partially representative of real use conditions and lacking the resource-efficient reuse of these solutions across multiple vehicle platforms. In order to fully exploit the potential of software-defined ZEV functions and vehicles, an advanced dedicated digital development framework is needed.

Proposal under this topic should address most of the following aspects:

- Design and validation of robust digital tools to efficiently and effectively develop complex ZEV that are increasingly software-defined.
- Advanced methods for development of trustworthy (24/7 available, secure, safe) software-defined ZEV solutions.
- Promoting the use and adaption of conceptional tools and demonstrate integration into development frameworks for virtual approval (early demonstrators) that are applicable to all ZEV types considered in 2Zero.
- Concepts enabling the feedback to and use of all types of data (e.g. engineering data, real-life operational data of ZEV) in the product development of software-defined vehicle functions including automated update of the applied digital tools and models.
- Improve product quality, improve decision making efficiency, quality, and understanding while at the same reducing overall development time.

D5-1-10. New designs, shapes, functionalities of Light Commercial Vehicles (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL XX by the end of the project – see General Annex B.

<u>Expected outcome:</u>

Projects are expected to contribute to the following outcomes:

- Develop mission focused and efficient LCV Battery Electric vehicle concepts.

- Increase affordability of the solutions.

Scope

The focus will be to identify and overcome main barriers for the development of new LCV concepts for urban and sub-urban mobility.

Projects are expected to contribute to the following:

- Develop and integrate new concepts to fill the gaps identified in the use cases.
- Develop optimisation priority strategies to have the largest environmental impact.
- Development and demonstration of combined usage of people and freight vehicle operation, fleet utilisation optimization in dense-urban, inter-urban, suburban and rural operation.
- New possibilities of enhanced vehicle fleet usage through connectivity features can be investigated.

The topic will also investigate the combination of fleets through holistic system-of-systems analyses (e.g. external data) of mobility and logistics on transport efficiency, congestion, energy efficiency, emissions and safety. The results of these analyses will be implemented in fleet usage and management demonstrators.

D5-1-11. Measuring road transport results towards 2Zero KPIs

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	CSA
Technology Readiness Level	Activities are expected to achieve TRL XX by the end of the project – see General Annex B.

Expected outcome:

Proposed project outcomes are expected to cover each of the following:

- A means to account for the contribution of the 2Zero Partnership, the immediate results of its projects, towards its goals (as measured by the KPIs).
- A means to identify and, where possible, quantify interactions and consequences, as a result of the information gleaned from the 2Zero Partnership project results.
- Recommendations on the areas for further development of such means.

Scope:

- The proposal must be able to generate results related to the specific, partnership KPIs, how they are predicted to vary (as a consequence of the project outcomes) between the period 2025 to 2035.
- The proposal must take advantage of the capabilities and techniques generated through the development and delivery of digital twin representations of the results of the 2Zero projects.
- Proposal must address at least the means of measuring those parameters of the 2Zero KPIs: more generically, climate, air quality, circular economy aspects could also be quantitatively projected.
- The proposal should take account of Open Science, its practices and learning, and project's results must be enacted in line with FAIR principles for data.

D5-1-12. EU Member States research policy cooperation network to accelerate zero-emission road mobility (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	CSA
Technology Readiness Level	Activities are expected to achieve TRL XX by the end of the project – see General Annex B.

Expected outcome:

European Commission and Member States are reinforcing and developing their research & innovation policy to accelerate zero-emission road mobility development. A framework for cooperation will enhance the efforts to achieve this pan-European challenge by joining forces, sharing knowledge, bundling financial resources and coordinating activities, creating complementarities, coherence and building synergies across the EU (e.g. 2Zero partnership) and Member States´ R&I funding programmes, national plans, efforts, approaches and incentives.

Action results are expected to contribute to all the following outcomes:

- Supply by participating MS and AC of data on national projects equivalent to those present in the CORDIS database, and timely update of a specific database to be set up or integrated in the existing Commission TRIMIS framework.
- Stronger harmonised national policy plans, efforts, approaches, incentives with a focus on R&I funding programmes of the different Member States (MS) and Associated Countries (AC), accelerating zero-emission road mobility.
- Maximally deployed and effectively utilised synergy effects, pooled resources and aligned R&I funding programmes across Member States to support the EU 2030 and 2050 CO_2 emission goals for the road mobility sector in an affordable and effective way.
- Exchange of knowledge and experiences and mutual coordination at multiple levels, implementation activities, regulations, incentives and demonstrations and the sharing of data.
- Provide companies, regions, cities and the research community with a holistic overview of policy plans and R&I funding programmes across EU to maximise synergy effects and the efficient utilisation of resources, such as from recovery packages and cohesion funds.
- Long lasting, strong coordination and cooperation between the European Commission, Member and Associate States and the Stakeholders involved in the 2Zero Partnership, facilitated by the States Representatives Group.

Scope:

Although there is a relatively large degree of similarity in the targets and approaches of the EU Member States and Associate Countries to address the climate change targets, still considerable differences in the paths can be observed: more coordination and collaboration is urgently needed to promote zero emission road mobility. Building on the policy cooperation network of the Member States built-up in ERA-NET Transport, Electromobility+ and ERA-NET Co-fund Electric Mobility Europe (EMEurope) with over two decades of experience, the action should:

- Address zero-emission road mobility for people and goods. Programmes supporting all phases of the innovation: technology development, demonstration, deployment and implementation will be considered.

- Allow the European Commission to better take into account national projects and their results in the development of their research and deployment actions.

- Develop a long-lasting network (beyond the project duration) of public and private stakeholders connecting Member States and European initiatives, under the umbrella of the 2Zero partnership SRG (e.g. ALICE, ETIP SNET, EPoSS, ERTRAC and POLIS) to share knowledge, coordinate activities and bundling financial resources to achieve synchronicity, synergies and complementarity in the R&I-related plans, efforts, approaches, incentives and funding programmes to effectively support the EU and national objectives for 2030 and 2050.

- More concretely contribute to:

  - Support MS in implementing and accelerating priority actions identified in the 2Zero SRIA in coordination with the 2Zero States Representatives Group.

  - Collect and share, up-to-date and targeted information on European and national R&I funding programmes, demonstration projects and testing activities, test sites, living labs with their features and capabilities, standards, testing and assessment methodologies as well as programmes in the field of zero emission mobility in Europe and beyond.

  - Exchange knowledge and experiences on zero emission mobility programmes in Europe, building on and connecting existing database platforms, such as TRIMIS, 2Zero events and conferences, including the H2020RTR series, Member State's and stakeholder's information sharing portals (no new databases are expected to be supported).

Aviation

D5-2-1. Accelerating climate neutral hydrogen-powered/electrified aviation (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Eligibility conditions	Activities are expected to achieve TRL 2-4 by the end of the project – see General Annex B. Activities should exploit synergies with the Clean Aviation (CA) partnership, with an eye towards their review, selection and further development during the second phase of CA.

Expected Outcome: Project results should focus on transformative technologies that address existing technology gaps for an aircraft liquid-hydrogen (LH2) powertrain of a megawatt class. Project results are expected to contribute to at least one of the following expected outcomes:

- Deliver transformative aircraft energy storage, conversion and distribution technologies for hydrogen and electrified-propulsion that exceed the state-of-the-art.
- Deliver novel heat dissipation, thermal management and recuperation technologies for megawatt class, that exceed the state-of-the-art.
- Deliver advanced simulation tools, validation methodologies and control approaches for an aircraft liquid-hydrogen powertrain of megawatt class.

Scope: The proposal is expected to develop further transformative technologies, at low TRL, that have potential to contribute to aviation climate neutrality by 2050.

Hydrogen as energy carrier has the potential to eliminate aviation CO2 emissions as well as reduce non-CO2 ones. Key enabling technologies for aircraft thermal and power management have been identified as showstoppers for their integration.

Beyond the development of transformative systems, the topic may consider the development of innovative control approaches as well as simulation tools and validation methodologies for LH2 powertrain of a megawatt class. The development of dedicated test benches (at a TRL range within the scope of this call) should exploit synergies with the CA (cf. note).

The topic aims to exploit synergies with the Clean Aviation partnership, towards developing transformative aircraft LH2 powertrain technologies, with an eye towards their review, selection and further development during the second phase of CA.

The topic is not open to hydrogen-powered/electrified new architectures, their integration and proposals for new aircraft configurations, as those are dealt exclusively in the Clean Aviation partnership. Higher prioritization will be given to transformative technologies from RTOs/Academia/SMEs with guidance from tier-1 suppliers and aircraft integrators.

Note: As the first WP of the first call of CA is expected by mid-March 2021, the next version of this topic may incorporate some additional scope and synergies with the CA WP.

D5-2-2. Competitiveness and digital transformation in aviation – advancing further industrial aircraft design capabilities (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Eligibility conditions	Activities are expected to achieve TRL 2-4 by the end of the project – see General Annex B.

Expected Outcome: Project results should focus on hybrid numerical/experimental procedures and methodologies that will advance further the industrial aircraft design capabilities. Project results are expected to contribute to at least one of the following expected outcomes:

- Multi-disciplinary and multi-fidelity design and optimisation integrated tools for industrial environment.
- New advancements in wing aerodynamics and aeroacoustics (with emphasis on interference), including data-driven (Artificial Intelligence – Machine Learning) high-performance computing and advanced validation-verification procedures.
- Methodologies such as data fusion, data assimilation and immersive visualization.

Scope: The proposal is expected to develop further advanced computational/experimental procedures/methodologies and industrial aircraft design capabilities that have potential to contribute to the digital transformation of the European aircraft supply chain.

Aircraft development requires testing for airframe, dynamic systems, propulsion and system and their sub-components in order to ensure their performance but also the highest level of safety. As a result, the proposal is also expected to develop methodologies and approaches dedicated to the use of combined experimental testing with numerical simulation in order to enhance the testing results and accelerate the development cycle.

The proposal should seek to exploit synergies with Clean Aviation (and big demonstrations in the second phase of the partnership) such as ground vibration testing, flutter mitigation, design of Ultra performant aircraft, advanced dynamic systems, H2 systems testing, thermal management, flight testing.

All developed hybrid numerical/experimental procedures and methodologies should be benchmarked (e.g. drag prediction, solver convergence, grid optimisation) for challenging industrial cases. Higher prioritization will be given to transformative procedures and methodologies from RTOs/Academia/SMEs, while guidance and explicit definition of the industrial challenging cases should be provided by tier-1 suppliers and aircraft integrators.

D5-2-3. Impact monitoring of EU Aviation R&I (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Eligibility conditions	The participants should work closely together with the relevant European Commission Services as well as European Aviation Safety Agency, SERAR3JU and the European Environment Agency.

Expected Outcome: Project results should deliver an impact monitoring toolbox of the European aviation research and innovation - integrating the impact of all Horizon Europe relevant aviation R&I actions along its three pillars and including actions beyond technologies and optimised operations (i.e. use of sustainable aviation fuels and market-based measures). Project results are expected to contribute to all of the following expected outcomes:

- Deliver a toolbox that will be the reference choice for the definition and assessment of environmental, climate and competitiveness policy options of future European aviation R&I and regulatory measures (e.g. support future European Commission Impact Assessments and assist Member States, EC and EASA in ICAO Working Groups and other International regulatory agencies. The toolbox should be able to perform trade-off studies, propose the most cost-effective policy options as a function of time (towards 2050) and allow policy makers, industry and scientists have informed discussions.

- Deliver life-cycle assessments of the air-transport system (including their infrastructures) and study how this compares with other transport modes. The involvement of EASA and DG-JRC in this outcome is deemed important.

Scope: The proposal is expected to develop a reference European toolbox able to assess the impact of European aviation R&I. The European Aviation R&I policy and aviation policy at large need a European tool (as open-source as possible) to assess what has been achieved and provide forecast analysis of the expected outcome of technological, operational, fuel and market-based-measures (MBM) choices. The toolbox should provide insight that will be used in the communication of the impact and achievements of European, National and private aviation R&I investments. Synergies with the monitoring and assessment of the Clean Aviation Work Programme activities, that will implement the Strategic Research and Innovation Agenda, should be sought. Synergies with SESAR 3 Joint Undertaking (in the scope of the project FlyATM4E) should be considered as well to expand approved climate-assessment methods and optimization of aircraft trajectories to identify promising mitigation options suitable to solve the task of reducing overall climate impact of aircraft operations.

The toolbox should:

- Incorporate methodological, science-based and validated models that can be traced;
- pay particular attention to non-CO2 emissions and climate-sensitive regions;
- integrate and make use of existing toolboxes developed in previous EU R&I Framework Programmes (e.g. TEAM_PLAY, CS2-TE);
- have different levels of fidelity for aircraft technologies and air transport system;
- have the most advanced interactive user interface and visualization tools;
- Be aligned with the European Commission open source strategy 2020-2023 and be made available for non-profit use for governmental/EU studies from EU Member States, EC Services, EASA and EEA.

D5-2-4. Aviation research synergies between Horizon Europe and National programs (WP2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Coordination and Support Action (CSA)
Eligibility conditions	Maximum two participants from each Member State – one of which at least should be responsible for managing National aeronautics R&I programmes. – cover communication activities until the end of Horizon Europe. Synergies with SESAR3JU work programme to be sought for the roadmaps.

Expected Outcome: Project results are expected to contribute to (tbd) of the following expected outcomes:

- Coordinate and support synergies between European, National and Regional R&I aviation programmes, including joint calls or other co-funding mechanisms aligning EU, National and Regional activities in specific fields.
- Set a "one-stop-shop" for efficient access and use of aviation research/technology infrastructure in the EU, and for facilitating the upgrade or creation of EU critical aviation research/technology infrastructure, including synergies with EU funding programmes such as EU Regional Funds and EIB.
- Facilitate the establishment of European aviation R&I roadmaps for noise, GHG emissions and sustainable aviation fuels.
- Contribute to the preparation of the European Aerodays 2024-2025 as well as other communication activities.
- Contribute to the communication of the impact of EU aviation research and relevant policies (Fit for 55, Industrial Strategy, Alliances, Space Policy).
- Support the Alliance on Zero Emission Aviation (AZEA) work with ad-hoc mapping and analysis, including identification of potential technology gaps and lack of related R&I and standardisation efforts. Contribute to the implementation of the AZEA roadmap to be developed by 2023 with appropriate progress reviews, consultations of AZEA members or representatives of the broader (European or international) air transport system, etc.

Scope: [*to be added]*

D5-2-5. Accelerating climate neutral aviation, minimising non-CO2 emissions (WP2024)

Specific conditions	
Expected EU	The Commission estimates that an EU contribution of XX million

contribution per project	would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Eligibility conditions	Activities are expected to achieve TRL 2-4 by the end of the project – see General Annex B.

Expected Outcome: Project results should focus to the minimisation of aviation non-CO2 emissions. Project results are expected to contribute to at least three of the following expected outcomes:

- Further increase the scientific understanding related to the impact of aerosols on clouds as well as the contribution of aviation NOx emissions to climate change.
- Strengthen a European network of experts in these areas.
- Perform detailed analysis of optimal relation between costs and climate.
- Perform flight tests and demonstrate the benefits and fuel burn trade-offs of avoiding climate sensitive regions.
- Perform hydrogen and aviation drop-in fuel research with an eye towards reducing further non-CO2 emissions.
- Develop real-time decision-support software tools for airlines and ATM, towards predicting and distinguishing the contrail and contrail cirrus formation with negative global warming potential.
- Present a detailed analysis of feasibility and benefits for an aircraft operator to monitor and report non-CO2 emissions in the EU ETS.

Scope:

EU-studies show that approximately 50-75% of aviation's climate impact is caused by non-CO2 emissions. It is because of their local geographical character, their dependency on atmospheric phenomena, the incomplete understanding and uncertainty as well as operational trade-offs that non-CO2 emissions have been less-targeted so far from international and European regulatory measures. Recent studies show that cost-effective mitigation measures are possible, provided that focused R&I actions together with flight tests resolve the final uncertainties. However, today any avoidance that increases CO2 emissions, even at a net reduction of overall climate warming impact, introduces a complex policy issue of mitigating short-term versus long term climate effects.

Recent EU and National-funded research activities (i.e. FP7-REACT4C, SESAR-FLyATM4E, ALARM, SINOPTICA, DLR-WeCARE, H2020-ACACIA, HE-BECOM) characterized better the contrail formation and provided more insight in the aviation NOx emissions and ozone formation. The studies also showed that if aircraft operations are only optimized for fuel use, they may have an increased climate impact, since non-CO2 effects may compensate the reduced warming from CO2 savings.

Avoiding climate sensitive regions has a large potential in reducing climate impact at relatively low costs without causing more CO2 emissions that outweigh the overall climate effect. The integration of data analytics and weather forecasting into advanced decision-support software tools that are able to predict real-time the contrail formation as well as propose alternative paths, are well in-line with the scope of this topic. This topic aims to integrate and provide clear operational guidelines supported by validated flight tests.

Synergies with SESAR should be exploited. Furthermore, international collaboration at research or Air-Traffic Management level could be considered.

Synergies to be considered with the Digital Sky Demonstrators on Aviation Green Deal, including in particular flights for demonstrating Green trajectories or equipped with sensors to collect data for the assessment of the non-CO2 impact on aviation.

D5-2-6. Competitiveness and digital transformation in aviation – advancing further composite aerostructures (WP2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Eligibility conditions	Activities are expected to achieve TRL 2-4 by the end of the project – see General Annex B.

Expected Outcome: Project results should focus on advancements in composite aerostructures and deliver new tools and processes in support of the European aviation supply ecosystem. Project results are expected to contribute to at least two of the following expected outcomes:

- Advanced composite technologies, with emphasis on new designs, high-volume manufacturing with integrated inspection (for aerostructures and propulsion).
- Breakthrough technologies in coupled aerostructures-systems-propulsion integration.
- Cost-competitive maintenance and repair of composite aerostructures.
- Advancements in physical and digital research infrastructures, with emphasis on aerostructures for all aircraft configurations with emphasis on synergies with the three Clean Aviation (CA) Strategic Research and Innovation Agenda (SRIA) thrusts, with an eye towards virtual certification.

Scope: The proposal is expected to develop further advanced composite design and manufacturing technologies that have potential to contribute to the digital transformation of the European aircraft supply chain.

The proposal is expected to give emphasis to cost-competitive manufacturing and maintenance of composite aerostructures. Composite multifunctional innovations that result from closer aerostructures-systems-propulsion integration are expected to be addressed.

All developed advanced composite technologies should be scale-demonstrated in relevant challenging industrial cases.

Note: This topic will be further detailed, upon receiving input from the Technical Committee and Scientific Advisory Board of CA, by the end of March 2021. The objective is to complement and accelerate the impact of the SMR and Regional sustainable industrialisation/digitalisation topics.

Waterborne transport

D5-3-1. Developing the next generation of power conversion technologies for sustainable alternative carbon neutral fuels in waterborne applications (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Technology Readiness Level	4-6

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- Establish the basis for the on board deployment of power conversion technologies for sustainable alternative climate carbon neutral fuels by 2030;
- Demonstrate the technical feasibility of the use of innovative power conversion technologies for sustainable alternative carbon neutral fuels in waterborne transport;
- Prove the scalability to power outputs significantly above 3 MW with acceptable power density and high efficiency;
- Demonstrate resilience of the power system to likely fuel impurities and variability of the power required by the ship;
- Develop a realistic pathway to the wider use of power conversion system technologies in waterborne transport providing implicated risk assessments, assessment of the lifetime of the power conversion system, maintenance scheme and the life cycle cost throughout useful vessel life;
- Where relevant, be coherent with related Horizon Europe activities, such as for example, the Batteries co-programmed partnership and the Clean Hydrogen Joint Undertaking.

Scope: Sustainable climate neutral fuels with emissions considered on a full well to wake life cycle basis are expected to be essential to decarbonise deep sea, large scale and energy intensive shipping, with their associated high power demands. A range of candidate fuels are advocated, including for example liquid and gaseous advanced bio fuels and liquids, advanced synthetic renewable energy carriers, green hydrogen, green ammonia and green methanol. Whilst power conversion technology for these fuels, include novel ICEs and fuel cells is being addressed by ongoing R&I and power outputs are slowly increasing, in most cases, they remain well below that needed as a primary power source for commercial shipping and some are very sensitive to fuel impurities within an environment where high purity cannot always be assured. Furthermore, large uncertainties with respect to the operational and capital costs are a barrier for new technologies being taken up in the market.

To be widely deployed, new power conversion technologies must be technically and economically acceptable for integration onboard ships. They must be capable of delivering high powers for prolonged periods and with power density which would be acceptable for integration within ship structures and high efficiency, without increasing air pollutants. Progress beyond the state of the art is required. To facilitate the scalability the developed power conversion technology has to be robust to the typical fuel qualities and expected contamination within a waterborne transport environment as well as potentially from combinations and blending different fuels, while maintaining endurance and reliable power output with reduced air pollution. Power conversion technology must also be robust under variable power demand, experienced in typical seaways and ship manoeuvres.

The topic is open to all zero carbon or climate neutral fuels and all energy conversion technologies, including but not limited to Internal Combustion Engines, Turbines and fuel cells. The objective is to develop and demonstrate, in a laboratory or simulated environment, validated power conversion technologies for sustainable alternative carbon neutral fuels. The scope of work includes ship configuration, performance simulation and scenario comparisons to enable the use of one or more fuels onboard the ships and study potential fuel blends as solutions to reach required power conversion performance and lowest possible levels of noise and air pollutant emissions (SOx, NOx, CO, PM, ammonia slip). One of the challenges is to demonstrate resilience to fuel impurities accepted by the power system and to cope with the variable power demand. The projects should provide assessment of lifetime of the power conversion and fuel system, and the life-cycle cost throughout vessel life. The project outputs and results should provide valuable contributions to regulations both at the EU and IMO framework. KPIs to be demonstrated include minimum 3 MW power output; minimum. 10 kW/m3 power density; minimum. 45 % total system energy efficiency including all required ancillaries with zero carbon or climate neutral operation weighted over the E2 or E3 cycle, as well as meeting expected safety KPIs for the use of fuel concerned, in particular with respect to green ammonia and methanol. When appropriate, collaboration shall be ensured with related Horizon Europe initiatives, in particular with respect to hydrogen, sustainable fuels and batteries.

This topic implements the co-programmed European Partnership on 'Zero Emission Waterborne Transport' (ZEWT).

D5-3-2. Demonstrating the safe use of new sustainable alternative climate neutral fuels in waterborne transport (2024)

Specific conditions[70]	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting

[70] These are the absolute minimum conditions. Additional conditions may be added as needed (see section 1).

	different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	7

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- Contribution to the establishment by 2027 of at least two full scale demonstration projects using or potentially using 100% climate neutral low emission sustainable fuels in a realistic shipping environment;
- Enable the timely transition to climate-neutral or zero-emission ship operations by facilitating the wider adoption of climate neutral sustainable alternative fuels at a large scale and for ships requiring prolonged autonomy;
- Support the conditions for a timely and efficient uptake of sustainable alternative fuels along the specific supply and usage chain for maritime transport and inland navigation;
- Demonstrate a sustainable alternative fuel system on board in full operations including fuel distribution, bunkering, power conversion and possible residue handling in a realistic environment on-board;
- Demonstrate the applicability, in particular with respect to the stricter environmental expectations for passenger ships;
- Provide risk assessments, mitigation measures, pre-normative R&I and proper demonstration towards regulation proposal;
- Where relevant, be coherent with related Horizon Europe activities, such as for example, the Batteries co-programmed partnership and the Clean Hydrogen Joint Undertaking.

Scope: Whilst smaller scale demonstration of vessels running on potentially climate neutral fuels is well established within the waterborne transport sector, large-scale demonstrations which include significant end-to-end operations, safety, environmental effects and risks are still lacking and are required as a trigger to the wide adoption of sustainable alternative fuels (SAFs) within waterborne transport. Adoption of SAFs within waterborne transport assets will be possible only if the outstanding challenges of the daily operations are solved; bunkering, storage, handling onboard have to be proven safe. SAFs come with potential new safety issues, such as toxicity, different flashpoints or fire hazards compared to fuel oil, which need to be mastered before deployment. Actual performance and efficiency of the overall system in full operations has to be demonstrated, especially air pollution (NOx, SOx, PM) and the well to wake GHG emissions as well as the required system, sub-system, process, and components needed for the handling and use of SAFs. Continuous emission and performance monitoring systems integration represent an additional challenge that should be taken into consideration including the monitoring of emissions profile and identifying operating patterns that require optimization. Activities will also underpin the pre-normative R&I required to facilitate the routine deployment of SAFs

Demonstration within operational conditions is targeted. With minimum power of 1MW (for either full or partial vessel power) going beyond state-of-the-art, the scope of work is to develop and demonstrate a SAF system on board in full operations including fuel distribution, bunkering, power conversion and possible residue handling. Addressing higher powers which will be applicable to a wider range of applications is encouraged. The aim is to increase confidence in and acceptability of the viability of climate neutral SAFs, including for example sustainable liquid and gaseous advanced bio fuels and other advanced intermediate bioenergy and synthetic renewable energy carriers, green hydrogen, green ammonia and green methanol and associated power systems. The project should provide risk assessments, mitigation measures and demonstration supporting the development of safety provisions in regulation proposals both in EU and potentially IMO and ISO frameworks. KPIs to be demonstrated include: ship power optimization; bunkering specificity (equipment, safety, operations, flowrate); energy consumption efficiency in waterborne transport; reduction of the global impact of the GHGs; reduction of the air pollution emissions (SOx, NOx, CO, PM) in a range of operating scenarios; safety in the most demanding applications such as passenger ship; safety assessment, norms and approvals. Demonstration should be compatible with relevant standards such as for example the Revised Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process as approved in 2015 (MSC/-MEPC.2Circ.12/Rev.1)

In the case that the proposal will address hydrogen and hydrogen derived fuels, synergies must be assured with the activities of the Clean Hydrogen Joint Undertaking and relevant supported projects.

This topic implements the co-programmed European Partnership on ‘Zero Emission Waterborne Transport’ (ZEWT).

D5-3-3. Achieving high voltage, low weight, efficient electric powertrains for sustainable waterborne transport (2024)

Specific conditions	
Expected EU contribution per	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting

project	different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Technology Readiness Level	Activities are expected to achieve TRL 3-5 by the end of the project – see General Annex B.

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- Demonstrate increased performance, efficiency and reliability of battery installations in high voltage on board distribution systems and thereby facilitate the greater deployment of battery electric shipping.
- Development and validation of battery real-time condition monitoring systems with predictive analytics integrated algorithms.
- Demonstration of high capacity energy storage systems above 1 MWh directly interfaced to medium voltage AC (3.3 kV or above) or DC (above 1 kV) power systems, by modular approaches.
- Design of efficient and redundant conversion systems for modular systems with low voltage battery modules at floating potential.
- Cost-effective insulation design for integrated battery modules and conversion systems.
- Feasibility of a low weight, high-energy density Li-Ion battery concept in demonstrators, considering maritime and inland waterway transport applications.
- Evaluation of sustainable life cycle management of electrical energy storage systems.
- Integration of intrinsically safe High Voltage DC Circuit Breaker technology.
- Power Systems predictive analytic integration.

Scope: The voltage level of battery installations onboard vessels is typically limited and within the regulations for low voltage installations. By increasing the voltage level of the onboard distribution system, the energy conversion can achieve higher efficiencies and be more compact, due to the smaller cross-sectional area of conductors and lower losses. However, for waterborne applications, challenges remain related to the design of conversion systems and insulation methods for integrating low voltage battery systems in high voltage AC or DC distribution systems. The necessary regulatory aspects need also to be defined to facilitate market take up for waterborne transport applications. Although high-voltage Li-Ion battery packs may be presently applied the current state-of-the-art still offers solutions that are too heavy to enable electrification of a wider range of larger maritime assets. However positively, installed waterborne battery packs now have much lower weights due to the latest improvements e in materials and technology for solid-state e-mobility battery solutions. Further study of the adaptation and the onboard integration solutions available for the lately developed Li-Ion technology (NMC, LTO, SLMFP) is needed.

Building on the current state of the art (without duplicating the results) and also ensuring synergies with the Batteries Partnership and in particular the 2021 topics HORIZON-CL5-2021-D2-01-02 and HORIZON-CL5-2021-D2-01-03, solutions should be developed which will substantially increase progress towards the battery electrification of a wider range of vessel types, for both the maritime and inland waterway transport which are characterized by larger battery systems and longer autonomy.

Projects are expected to address the following aspects:

- Design of battery management systems of high voltage battery installations for AC and DC distribution systems in waterborne transport.
- Design and control of conversion systems, insulation design and insulation coordination.
- Adoption of low weight electrical energy storage designed to be integrated on board (not a container).
- Sustainability and circularity criteria to be preferably adapted for whole life of on-board battery pack solutions (i.e. second-life applications).
- Identification and characterization of the specific requirements needed for inland waterway and maritime transport.
- Development of battery safety concept, especially for large battery spaces onboard, considering detection, ventilation and fire suppression technology.

The new solutions should also contribute significantly to the overall safety for on-board battery applications (i.e. for toxic emissions, fire propagation, etc.). The form factor, battery management system, interface with the shore side electric grid should also be considered.

This topic implements the co-programmed European Partnership on ‘Zero Emission Waterborne Transport’ (ZEWT).

D5-3-4. Combining state-of-the-art emission reduction and efficiency improvement technologies to ascertain new-built and existing ships being compatible with the "Fit for 55" package objective by 2030” (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 5-7 by the end of the project – see General Annex B.

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- At least three market ready design solutions will be developed to address short sea shipping, inland waterway transport and high seas shipping applications making use of combinations of high TRL emission reduction technologies and improved operational efficiency to reduce emissions from shipping in line with the expectations within the EUs “Fit for 55” legislative package.
- Development of an open source design assessment tool which can be used to assess the operational Carbon Intensity of vessel designs and to assess their progress towards achieving emissions reductions consistent with the EU’s ‘Fit for 55’ package objectives and the IMO’s Carbon Intensity Indicator.
- Facilitates the continuous improvement and upgrading of existing vessels to increase efficiency and reduce emissions through the measurement and bench marking of operational profiles, including through the use of digital twin modelling and data.
- Within a relevant operational environment, quantify the contribution from the applied emission reduction technologies, designs and operations separately and jointly towards the reduction of emissions.
- Enable assessment of the retrofit and refurbishment options of applied emission reduction technologies.

- Support the accelerated conversion of inland and marine ships towards better energy efficiency and reduced emissions.

- The developed design concepts have robust business models to ensure a high probability of commercial European deployment and the expectation of becoming operational by 2030.

Scope: Legislative proposals within the EU's "Fit for 55" package targeting the reduction of waterborne transport emissions will assess emissions reductions on the basis of operational data collected within the frame work of the EU's MRV regulation. Internationally, the forthcoming IMO Carbon Intensity Indicator and Data Collections System (DCS) will be used. Vessels visiting EU ports will need to provide data so as to ensure compliance with both MRV (EU) and DCS (IMO) data requirements. This change from assessing emission reductions based on design to the direct measurement and verification of actual operational emissions requires a new approach to design. As a consequence, the vessel design process will need to employ digital modelling and simulation techniques which take into account the vessel's expected operational profile and life cycle so as to ensure that the delivered ship or modification will deliver the expected emission reductions in the "real world"

For new builds, present improvements in ship energy efficiency have reduced consumption by 15-30% compared to equivalent reference ships in 2008. This topic aims to combine state of the art solutions developed, including those addressed within earlier calls as well as other developments to produce at least three concept vessels which will further improve operational efficiency by at least 20% and improve on board energy efficiency by over 10%.

Projects will develop at least three vessel design concepts, in addition in may also develop retrofit concepts. An innovative holistic/systemic approach shall be applied to the design which is founded based upon total ship energy needs for use within reference operating profiles and business cases.

This "design for operation" approach will integrate and combine both operational energy savings and emission reduction technologies. The technologies and solutions to be integrated have been already demonstrated or at least developed to TRL 6 or 7. Example solutions for consideration may include power conversion/electrification /energy devices, sustainable low emission fuels, HVAC, energy storage, operational strategies, smart energy monitoring, wind assistance, solar, air lubrication, cold ironing, slow steaming with just in time scheduling, hull coatings and cleaning, hydrodynamics and propeller designs etc.

Activities will address energy system modelling and fast simulation assessment so as to demonstrate the expected energy efficiency gains and emission reductions achieved by the resulting designs within their operating reference cases.

The minimum of three use cases shall include the following vessels types; short-sea, inland waterway and high-seas. For each vessel, both refit & new-build versions shall be addressed. Projects may possibly include the development of a decision support system to facilitate the most effective implementation of operationally driven energy efficiency improvements.

When appropriate, as required for the design process, activities may also address the definition of a secure knowledge sharing platform which is IP secure so as to enable the necessary data transfer with respect to the detailed performance and characteristics of the integrated systems, component performance.

Business models will be developed to facilitate the deployment of the resulting concepts, in particular addressing financing, market needs and possibilities to support first of a kind deployment, taking into account opportunities within EU support schemes such as the Connecting Europe Facility, Climate Change Innovation Fund and regional funds. Proposals which demonstrate a clear and credible pipeline from development to the operational deployment of the developed designs following the projects end will be particularly welcome

This topic implements the co-programmed European Partnership on 'Zero Emission Waterborne Transport' (ZEWT).

D5-3-5. Design, test and demonstrate technologies to minimise underwater noise generated by waterborne (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 6-8 by the end of the project – see General Annex B.

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- Develop understanding on effectiveness, safety and cost-effectiveness of noise mitigation devices, mitigation measures and management options;
- Deliver standards for the specification of source noise levels by suppliers and which build upon the current state-of the art;

- Test and demonstrate through significant dedicated large scale demonstrators or retrofitted ship with URN reduction modifications providing results of reduction achievements and noise levels radiated;
- Raise awareness and inform EU ship owners of their environmental impact from underwater noise and on technical possibilities to optimize noise reduction so as to minimize harm to the marine environment;
- Provide advice to regulators concerning noise from waterborne transport depending on operational status, weather conditions, loading conditions, the frequency and type of noise and its impact on the environment for consideration within any forthcoming regulation.

Scope: Whilst on-going research seeks to characterize the underwater radiated noise (URN) posing the greatest threat to aquatic species and the marine environment as well as potentially promising solutions to reduce the impacts from URN, the demonstration of technologies to minimize the harmful impacts from waterborne transport URN remains less developed. Current on site URN measurement campaigns do not address all potential waterborne transport related noise sources and selecting suitable mitigation measures remains a challenging task as there are many options for URN reduction. Consequently assessments need to be made on a case-by-case basis, potentially taking additional environmental, operational and economic factors into account. An important challenge is to predict URN at the design stage in order to be able to design and implement less noisy solutions from the early stage. This challenge is faced at equipment design level and at ship integration stage. The same ship operates at various speeds, loads and sea states which contribute to the challenges of designing a quiet ship in large range of conditions. Another challenge is to have a measurement system onboard. Regulations nowadays only focus on controlled circumstances (fixed speed, no waves, etc.). The consideration of co-benefits or at worst neutral or negative impacts for GHG emissions should be considered.

Activities should include developing methods and modelling to predict and measure under water radiated noise in order to integrate a noise reduction optimization. The project will build upon the current state of play to support the development of standards for the specification of source noise levels by suppliers,. The project should conduct modelling and field studies to improve understanding on effectiveness, safety and cost-effectiveness of noise mitigation devices, mitigation measures and management options in different sea states and in different ship loads. The identified solutions should be tested and demonstrated through large scale demonstrators such as for example sea trials with innovative propeller or other URN mitigation solutions or modifications. Projects should develop systems for on-board measurement of noise instead of separately deployed sound buoys. Information concerning sound ranges could benefit the development of a decision support system to reduce radiated noise whilst maintaining energy efficiency and normal operation. In addition the project should address communication towards the European ship owners and operators so as to raise awareness, inform them of their environmental impact and on technical possibilities to reduce their noise and its impact on the underwater environment. The project will seek synergies with related projects and activities addressing underwater noise, including from non-transport sources and will provide advice to regulators on the consideration of waterborne transport related factors such as weather conditions, loading conditions, frequency and amplitude, etc., within any potential regulations.

This topic implements the co-programmed European Partnership on 'Zero Emission Waterborne Transport' (ZEWT).

D5-3-6. Integrated real-time digital solutions to optimise navigation and port calls so as to reduce emissions from shipping (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 6-8 by the end of the project – see General Annex B.

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- Improve the operational efficiency of ships when arriving to/departing from ports, towards elimination of offshore waiting time.
- Reduce ship emissions through voyage and port arrival optimisation so as to facilitate more efficient sailing speeds. As a consequence greenhouse gas emission reductions of 10 to 20% should be possible.
- Establish a full scale demonstration on existing routes and services involving at least 3 ports and 2 shipping companies and other stakeholders. Quantify reduction in emissions compared to business as usual.
- Assessment and quantification of the benefits of port and navigation optimisation for different types of maritime traffic, e.g. tramp and regular services for bulk, container, passenger, Ro-Pax, Ro-Ro, etc.

- Development of business models to prove the commercial viability of voyage and port call optimisation and facilitate take up.
- Solutions that are suitable for a wide range of conditions and types of service.
- Assessment of safety aspects in comparison with current situation, considering situational awareness during port entrance, manoeuvring, berthing and departure (preserving the necessary level of skills).
- Practical demonstration of port call optimisation standards considering the on-going standardization initiatives by IMO/ISO groups and development of operational roadmap(s) for standard technical committees.
- Development of the harmonised standards and collaborative frameworks needed to facilitate a secure and resilient operational, real-time digital data sharing and decision support system for port and voyage optimisation.
- Substantial progress beyond existing smart voyage and port call optimisation tools.

Scope: Shipping is frequently subject to prolonged waiting periods offshore before birthing and offloading cargo. Ships waiting offshore pending the availability of port capacity reduces operational efficiency as well as increases emissions, either whilst waiting or due to faster sailing speeds in order to arrive at port in case of an available birth. To avoid these situations, port call optimisation systems have been developed and are now being piloted. However, these have been generally limited to specific container services. More widely applicable navigation and port call optimisation tools which can address the entire voyage, promote the most efficient sailing speeds to reduce emissions and ensure direct birthing without delay could substantially improve operational efficiency and reduce emissions. Activities should take a holistic approach to the development and scale up of an integrated port scheduling and voyage optimisation tool. Development should go beyond the capability of the first presently deployed pilot systems at both ship and port level. The development of standards should be developed to enable the application of an integrated optimisation system across the range of concerned stakeholders and their operations. System security should also be taken into account as well as its resilience and mitigation actions in case of failure. O A pilot integrated port call and voyage optimisation tool shall be developed which progresses beyond optimisation of individual port calls to address real traffic (multi-ship) scenarios, focussing on ship routing, voyage optimisation, minimising emissions and finally the port call process. A wider focus on more efficient planning and optimisation of voyages, ship routing, fleet planning and scheduling shall be undertaken which combines the perspectives of both shipping companies and the port call process. Such a systems is expected to particularly benefit deep and short sea shipping with the resulting optimisation expected to potentially achieve 10%-20% reductions in fuel consumption with corresponding reductions in GHG emissions. Projects will develop methodologies and tools that allow for information sharing and optimisation of routes and time of arrival in real time. To maximise emission reduction and operational efficiency benefits, the full voyage should be addressed, including ship positions far from port, to undertake for decision algorithms are expected to use AI, heuristics, weather, consumption, emission, traffic, port planning and data business analytics. . Harmonised collaborative standards shall be developed to facilitate operational, real-time digital data sharing and decision support systems to reduce fuel use and emissions and also optimise ship operations in relation to the port call process including cargo handling, port services, clearances commercial services such as bunkering, onshore power connections etc. The developed standards should take into account the integration with current and existing port infrastructures and their monitoring systems, security and system resilience. Risk assessment for these solutions should be carried out using existing models (such as FSA, HAZOP, etc.) to support safety and business continuity in case of failure as well as regulatory development at IMO and EU level. Shipping companies will be able to quantify their fuel savings and the GHG emissions avoided as a result of the optimisation system and the real-time information shared with ports during their voyage and the impact on port-hinterland transport connections. GHG emission savings will be maximised through a seamless optimised routing and sailing speed approach throughout the voyage from port call to the open ocean using modelling tools, when necessary developed within the projects, so as optimise arrival times, taking into account fuel use, sea conditions, the early allocation of port services, based on a multi-stakeholder approach in a real time situation.

Projects should build upon existing systems, technologies and regulations (for instance, European Maritime Single Window) to assure the research directly applicable with existing requirements, but also other innovative and new technologies can be deployed.

KPI´s for efficiency from real cases must be developed and measures, including calculation of the gains from the application of the solutions developed within the project. Demonstration shall be undertaken within a realistic environment to measure the resulting reduction in emissions achieved as a result of the voyage and port scheduling optimization system compared a typical similar non-optimized service.

This topic implements the co-programmed European Partnership on 'Zero Emission Waterborne Transport' (ZEWT).

D5-3-7. Structuring the Waterborne transport sector, including through changed business and industrial models in order to achieve commercial zero-emission waterborne transport (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.

Type of Action	CSA
Technology Readiness Level	NA

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- A full understanding of the business model and commercial barriers to the increased take up of low emission solutions for waterborne transport;
- Prediction of the timing and industrial capacity to retrofit the current European fleet to meet 2030 and 2050 emission reduction and pollution targets. Considering all vessels operating within the European region, in particular inland waterway transport vessels, short sea shipping services, ferries, cruise and offshore vessels;
- Concerning green shipping, a full understanding of the investment decision cycle, the existing gaps, and potential solutions to overcome these gaps;
- Building upon the ZEWT strategic Research and Innovation Agenda, development of an implementation and investment plan to ensure a timely achievement of zero-emission waterborne transport;
- Considering the relationships between financiers, vessel owners, operators, charterers, logistics companies, cargo owners, retailers and consumers, establishment of new business models which will better incentivize the use of low emission shipping and better meet the greening strategies of stakeholders in particular with respect to final point of sale;
- Increase commitment from the wider waterborne sector and wider social awareness through enhanced communication of the European waterborne transport sectors' activities to transform into a zero-emission, connected, automated and competitive sector.

Scope: The European Green Deal sets ambitious objectives to transform Europe into the first climate neutral continent by 2050 with the transitional objective of reducing emissions by at least 55% for all sectors by 2030, compared to 1990 levels and by 90% by 2050. Whilst at the same time ensuring that nobody is left behind, supporting new opportunities for innovation, investment and jobs. This presents a valuable opportunity for the European industry, in particular for waterborne transport where Europe leads in high technology and green energy efficient shipping development. As well as reducing emissions and increasing efficiency, digitalization of waterborne transport will further increase safety, security, and reliability.

Whilst Europe is still a worldwide leader in advanced, digital and green shipping, there is a lack of take up of new technologies within the wider waterborne market. In part this is a reflection of the sectors conservatism and reluctance to change unless driven by regulation. It is also hindered by the complex commercial structures and finance models which can distances the interests of: ship owners who commission new builds, financiers who commoditize vessel value by type, operators who can benefit from lower fuel consumption as well as cargo owners and final points of sale where the use of low emission shipping can be a potential commercial advantage. Whilst new business models and labelling schemes to better incentivize green shipping have been developed, they are yet to be widely established and are largely unknown. There is a need to objectively analyze the sectors of the waterborne transport market and within each sector characterize the business models, identify the barriers to the take up innovative green shipping solutions and work with the stakeholders to propose commercial models which can provide a better incentive for increasing the green shipping fleet.

The complexity and large number of sub-segments within the waterborne transport sector increases the benefits of a coordinated approach towards achieving a competitive transition towards zero emission connected, automated and competitive waterborne transport. This an important benefit arising from the Waterborne TP technology platform and the linked Zero Emission Waterborne Transport partnership which for the first time has brought together a critical mass of representing all aspects of the waterborne sector towards achieving this goal.

Furthermore, increased awareness of the general public and the broader non research waterborne sector regarding the commitment, ability and opportunities for European waterborne transport to develop and implement competitive solutions which will meet the ambitious objectives reflected in the European Green Deal.

To ensure a coordinated approach to zero-emission, digital, automated and competitive European waterborne transport, all stakeholders, including sub-segments, both private and public actors shall participate in a forum which will be fully integrated within the structures and decision making processes of Zero-Emission Waterborne Transport partnership and which takes into account results of relevant Horizon projects and other studies. In particular, the forum, possibly structured within smaller targeted working groups will:

- Develop concepts and assess operating; schemes, business models, deployment mechanisms, scrappage, labelling, financing, technology and construction programs and related policies to foster the accelerated reduction of emissions and the digitalization of waterborne transport. Including considering the deployment and use of sustainable alternative fuels and electrification. Also taking into account the differential of responsibilities between charterer, cargo owner, ship owner, point of sale etc.;

- Analyze the needs and timing to retrofit and replace the current European fleet (focusing on inland waterway transport vessels, ferries, short sea shipping, cruise ships and offshore vessels), combined with an overview of the European capacity (with respect to technology and skilled workforce) available to retrofit these vessels and identify any capacity gaps for the timely delivery of the decarbonized tonnage;

- Within different market segments, provide an analysis of where disincentives exist to the increased deployment of smart zero emission shipping, considering for example the investment decision cycle: finance models, bunkering and fuel supply infrastructure, availability, longevity and costs of technologies, possibilities to retrofit/build a vessel timely, properly skilled workforce, etc.

Founded upon a communication plan, implement a communication campaign towards key stakeholders including wider society, the non-research waterborne community, wider national and European policy makers regarding the strategic importance of waterborne transport R&I, the take up innovation, and its commitment to deploy smart zero emission solutions to the benefit of future generations and to deliver on the objectives of the European Green Deal Communications planning will include KPIs to assess the campaigns effectiveness and at least 3 review points where progress can be assessed and if necessary adjustments made.

This topic implements the co-programmed European Partnership on 'Zero Emission Waterborne Transport' (ZEWT).

D5-3-8. Coordinating and supporting the combined activities of member and associated states towards the objectives of the Zero Emission Waterborne Transport partnership so as to increase synergies and impact (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	CSA
Technology Readiness Level	NA

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- Increase the impacts arising from the Zero Emission Waterborne Transport (ZEWT) European partnership towards the achievement of zero emission waterborne transport in Europe.

- Leverage the efficiency of national and EU R&I investment to accelerate the development and deployment of zero emission waterborne transport for both European and national benefit.

- Further align national programs with the activities and outcomes of the ZEWT co-programmed European Partnership;

- Establish a cooperation mechanism between EU Member States and Associated States to jointly fund research related to the objectives of the ZEWT co-programmed European Partnership;

- Creating a critical mass and excellence in precompetitive breakthroughs related to the objectives of the ZEWT co-programmed European Partnership.

Scope: Currently, Member States and Associated Countries cooperate in the framework of the Horizon 2020 ERA-NET Co-fund MarTERA ("Maritime and Marine Technologies for a New ERA"). Within MarTERA, 16 countries joined forces to launch joint calls and support nearly 50 joint projects with about 250 and total €56M commitment. Valuable coordination was ensured between national and European research, including with the waterborne transport sector. The benefits from synergies remain towards the achievement of common goals which are largely reflected in the objectives of the ZEWT partnership. This requires better coordination and harmonisation of individual national funding programmes as well as consideration and alignment with the ZEWT partnership and its related calls and projects. Furthermore, national administrations are best placed to facilitate the increased participation of SMEs within European projects, aligned with the objectives of the ZEWT co-programmed European Partnership. The project will contribute to an advancement of the activities included in the SRIA of the Partnership, by aligning national research programmes with the R&I strategy of the Partnership and by attracting additional national funding to the Partnership. Activities may include the facilitation collaboration between member and associated states in a variety of configurations and possibly joint calls- however activities will not include support to the projects themselves and their management. In general, the focus will be on small, effective international consortia conducting precompetitive research (TRL 1 to 6) with European added value. In this way, the project will complement the considerably larger research undertakings directly funded through the calls of the Partnership work programme and thereby increase the impact of the ZEWT co-programmed European Partnership. Activities may also include reinforcing the complementarity of national schemes towards the take up and deployment of European R&I results which aligned with the objectives of ZEWT thereby increasing impact and value from European and national investment.

This topic implements the co-programmed European Partnership on 'Zero Emission Waterborne Transport' (ZEWT).

D5-3-9. Demonstrating efficient fully DC electric grids within waterborne transport for large ship applications (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 6-8 by the end of the project – see General Annex B

<u>**Expected Outcome:**</u> Project outputs and results are expected to contribute to the following expected outcomes:

- Reduced emissions from waterborne transport through increased electrification including hybrid power systems. Bench mark and quantification of achieved GHG emission reduction.
- A new configuration of the entire power generation architecture for large scale shipping conceived and ready to be deployed. This configuration will serve as a reference for a wide spectrum of ship's types using electrical propulsion and auxiliary power, including when for example founded upon electrical generation with ICE’s, fuel cells, shaft generators or shore power.
- Demonstrate the feasibility of a secondary smart DC grid (engineering framework, distribution/protection devices).
- Proof spin-off towards and from land-based smart DC microgrid development.
- Proof distributing main power based on DC instead of AC.
- Minimize operating costs and reduce emissions by cutting energy consumption and extending service intervals of the generator sets.
- Demonstrate smart management and control of hybrid electric plants, combining different energy sources obtained by the use of non-carbon fuels aimed at minimizing total lifecycle net GHG emissions.

- Maximize the efficiency and power density of the power in order to reduce the overall volume and weight.

- Develop new power electronic systems for AC/DC converters and DC interruption within the electrical network with higher efficiency.

- Integrate new power electronic systems within the ship's network with advanced control systems to cope with variable loads and high levels of DC currents to interrupt;

- Contribute to the development of standards.

Scope: Primary DC systems are now applied on multiple types of ships, employing battery energy storage. The application of DC grids on-board has already started and will grow significantly because of its promising aspects such as reduction of complexity, increased modularity and improved integration. Ways to unlock the full potential of a DC grid entire network for both primary and secondary (auxiliary) distribution, taking various onboard applications of ship's electrification systems (i.e. high-power fuel cells, batteries, etc.) into consideration are currently lacking. The project must realize flexible and functional integration of energy sources and loads and develop a smart plug-and-play DC system. The challenge is to focus not only on secondary distribution, but also on the integration/interconnection with new sustainable primary power systems in a DC grid network serving the entire ship. The project will develop the necessary components and standards. In addition, the project will research the impact of design choices, safety measures and integration on the ship. This will require the development and onboard integration of high power equipment and systems to complement the electrical grid (e.g. solid-state protection, solid-state transformers, Silicon-Carbide Power Devices, DC motors with permanent magnets, etc.). All stakeholders should be part of the development: distribution and protection manufacturers; engineering companies, manufacturers of electrical users, shipyards, etc. The project must develop a new concept of flexible DC power grid by leveraging on new power electronic systems and allowing for different DC power generation systems based on sustainable alternative sources.

The solutions must address the following aspects:

- Develop high TRL innovative power electronic systems (e.g. converters, circuit breakers with logic selectivity) adapted and certified for waterborne transport applications.

- For waterborne transport, develop a new concept of flexible DC power grid by leveraging on new power electronic systems and allowing for different DC power generation systems based on sustainable alternative sources.

- Develop a prototype system at small scale (min. 100kW) in real waterborne transport environment conditions, and demonstrate the functionality and the integration of various components and proving further upscaling possibilities.

- Validate the system with classification societies ensuring the highest standards for safety and reliability.
- Develop standards for DC ship board microgrids and communication protocols. Microgrids are necessary especially for large ship applications where differentiation between zones (zones with ICE and zones with RES systems) is inevitable.
- Projects should address a range of ship's electrification solutions, such as for example high power fuel cells hybridized with high power batteries.
- Where relevant, synergies and collaboration shall be ensured with the related activities and projects arising from linked Horizon Europe initiatives, in particular the Batteries and Clean Hydrogen JU partnerships.

Substantial progress beyond the state of the art should be achieved. Demonstration on a relevant ship type to validate the research results will be important to prove the applicability towards a range of vessel types, with larger battery systems and longer autonomy.

This topic implements the co-programmed European Partnership on 'Zero Emission Waterborne Transport' (ZEWT).

D5-3-10. Advanced digitalization and modelling utilizing operational and other data to support zero emission waterborne transport (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex B

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- Development of a platform for Integrated Green Digital Twins (DT) which provide a basis to continuously improve the environmental performance of vessels over their entire life cycle;

- Use model based systems engineering, simulation and hardware in the loop approaches to prove the applicability of the platform to a wide variety of vessel operations throughout its lifetime,

- Ensure the system will be adaptable to consider all potentially relevant retrofits needed to meet future regulation and changes in operational profile both during initial design and throughout the vessels life-cycle.

- Ensure the Green DT allows for optimization of the ship's equipment in operational conditions so as to provide the best environmental and economic solution for a given waterborne transport operation;

- Projects must make best use of available (simulation) concepts and consider all relevant life-cycle aspects, including end of life disposal.

Scope: Present state-of-the-art of Digital Twins (DT) applied to waterborne transport is typically characterised by a limited focus on specific aspects of design or operation of a vessel on the basis of numerical simulations. Waterborne DTs which take an integrated approach to combine design and operation to improve efficiency and reduce emissions are not well addressed and aspects of open (software) architecture, data standards, security guarantees and data sovereignty of data owners are not comprehensively addressed. Whilst some advances in data integration for different applications have been made, a comprehensive global integration of data remains missing. These higher levels of integration between different functions of a DT, e.g. during design and operation of waterborne assets require both complex multi-physics simulations and advanced levels of data organisation. This leads to the need for higher computational efficiency to meet future requirements in terms of accuracy, and the integration of (the digital representation of) suitable technologies for dedicated Green vessels.

Digital Twin(s) of Green vessels need to evolve and be applicable throughout the life cycle of the vessel, from initial design, to detailed design, engineering and production, operations, retrofitting, and circular end of life. To make best use of a Green ship DT, it must allow addressing optimisation for enhanced energy efficiency and reduced environmental footprint in a consistent way throughout the life-cycle of a ship. This will require a thorough consideration of potential operational conditions as well as regulatory changes requiring e.g. retrofits, already during the design stages, thus enlarging the parameter space to be investigated considerably. The Green Ship DT will play a key role in design and operation of future zero or low emission vessels, and their through-life sustainability upgrades. Mapping all relevant data influencing operational environmental performance, it will be the basis for decision support for operational (AI-based) optimisation, for considering the use of e.g. propulsion changes (retro-fits, alternative fuel options as well as complete renewable energy solutions) and predictive maintenance.

Dealing with significantly enlarged data available for a vessel may require an efficient modular concept which makes use of advanced combinations of both cloud and edge computing in addition to new data organisation concepts also addressing data sovereignty of different data owners who contribute to the Green DT.

To meet the technical, economic and environmental challenges for waterborne transport assets, future Green DTs must address all relevant aspects of physics simulation, design and operational planning and optimisation as well as data organisation and storage, integrating also real data obtained from monitoring and measurements. The developed digital model of the vessel and its equipment (machinery, etc.) needs to allow for checking compliance with external rules and regulations, including their evolution as well as to map economic and environmental developments to provide decision support for operational changes, e.g. regarding the use of sustainable alternative fuels, renewable energy and suitable retro-fits as regulation and market prices change. Developments will use open standards, libraries and tools to create generic and reusable solutions applicable to a wide range of maritime assets. Here the interoperability of data models must be provided and relevant aspects of Data Ownership and Integrity as well as security against cyber and physical threats must be addressed.

This topic implements the co-programmed European Partnership on 'Zero Emission Waterborne Transport' (ZEWT).

D5-3-11. Developing a flexible offshore supply of zero emission auxiliary power for ships moored or anchored at sea deployable before 2030 (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 6-8 by the end of the project – see General Annex B

<u>Expected Outcome</u>: Project outputs and results are expected to contribute to the following expected outcomes:

- In close cooperation with ship owners and ports, demonstrate and testing of an innovative solution to provide auxiliary for ships moored and anchored at sea which can be deployable before 2030;

- Develop a solution which can be flexible in terms of area of application (i.e. can be re-deployed in other areas within a port, or be moved to other ports, both inland as well as sea ports where relevant);

- The solution will eliminate GHG and polluting emission from ships moored or at anchor;

- The solution will include a guideline on technical, operational and safety aspects;

- Assessment of the CAPEX and OPEX of the developed solution and optimization of the concept to increase the financial viability of the developed solution.

Scope: The provision of electric energy to vessels at port is a mature technology which provides important benefits in terms of reducing the emissions from the waterborne transport sector, not only for CO2 but also for other pollutants. Within Europe this is particularly important as many ports are either an integral part of densely populated cities or very close to them. The provision of onshore power supply (OPS) to vessels in the EU ports forms an integral part of the "Fit for 55" initiative. Due to direct electrification being more efficient, OPS is an important long term solution applying to vessels with other clean technology solutions which will become more widely available. So far the provision of OPS has been designed and applied for vessels securely berthed at terminals. This is an important step, which needs to be encouraged. However, in many cases, vessels need to spend important time at port anchorage, before a berth at a terminal is available. Some vessels such as cruise ship may on occasion, also disembark their passengers to tenders off shore. During this period, vessels are using their main or auxiliary engines, thus creating emissions which impact port cities and coastal areas as well. A solution thus needs to be developed which can provide OPS to these vessels whilst not at berth. Current consideration of such applications has been mainly limited to barge mounted solutions and concept development of offshore cabled power buoys (e.g. floating power plants, LNG HIVE2, OPS barges and offshore charging buoys). Generally solutions are not yet mature, in several cases use fossil fuels and a range of other possibilities may remain. The project should develop and test potential solutions for the provision of electric power to maritime vessels (primarily container ships and passenger vessels, including cruise ships) of at least 5000 GT.

Solutions shall:

- Be adaptable, so that as required, power can be provided to different locations within the port anchorage;

- Be based on direct electrification from shore grid connections or offshore renewable power or the use of sustainable alternative fuels including for example liquid and gaseous advanced bio fuels, synthetic renewable energy carriers or energies.

- Aim to minimize air pollution, including when solutions are founded upon bio fuels.
- When relevant, assess the possible use of circular energy sources such as those from industrial processes taking place within the port perimeter (chemical processing, scrap processing, melting etc.);
- Aim for operational deployment by 2030 deployment, minimize costs taking into account Capex and Opex with consideration of the energy conversion efficiency, the cost and availability of the supplied sustainable alternate fuels and/or energies;
- Pay particular attention to all safety aspects relating to the provision of clean energy, while a vessel is at anchorage.
- For example, the proposed solution maybe founded upon one of the following concepts, although other concepts may also be proposed:
    - Barge mounted generators, using sustainable low GHG fuels.
    - Floating energy storage units, using batteries together with inverters and a capability to provide the typical total energy need of a ship at a port anchorage.
    - Barge mounted fuel cells using green hydrogen fuel or other climate neutral sustainable alternate fuel.
    - Cabled offshore power supply connections towards buoys or other supply interface.
- Evaluate the range of applicable regulatory instruments by reaching out to relevant Authorities.

This topic implements the co-programmed European Partnership on ‘Zero Emission Waterborne Transport’ (ZEWT).

Other collaborative R&I

D5-3-12. Reducing the environmental impact from shipyards and developing a whole life strategy to measure and minimise the non-operational environmental impacts from shipping (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting

	different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Technology Readiness Level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex B

<u>Expected Outcome:</u> Project outputs and results are expected to contribute concretely to the following expected outcomes as market (‘’*’’) whilst supporting the overall medium and long term objectives:

- Reduce the non-operational environmental impacts from shipping including construction and end of life strategies.
- Understand the most significant environmental factors in shipbuilding and throughout a ships circular life cycle including ship repair and their associated costs.
- Enhanced environmental awareness of personnel awareness and development of skills for greening of shipyards so as to improve the environmental performance and productivity in shipbuilding and ship repair processes.
- Enhanced circularity of waterborne transport assets through recycling and re-use of materials, parts and components.
- Towards a longer term objective of a ship environmental performance index which would be an indicator of the non-operational environmental impacts from the ship taking into account its manufacture, embedded materials, capacity for repair and circular end of life strategies.;
- *A shipyard environmental performance index (SEPI), relevant KPI’s and benchmarks for shipyards through an inquiry into current shipyard processes and utilities (i.e. energy use and emissions to air, water and earth);
- *A (digital) catalogue of demonstrated (TRL7-8) advanced production processes with high potential for increased productivity, reducing waste and improving the shipyards’ environmental performance (SEPI) with respect to the current benchmarks by at least 20 %.
- *A generic digital shipyard model encompassing shipyard processes with the associated energy use and emissions, enabling to assess and benchmark the environmental performance and cost-efficiency of shipyards and their contribution to the environmental impact assessment within the ships’ Life Cycle (LC).

- *A guideline on technical, organisational and personnel training solutions for reducing energy use and emissions to air, water and soil and improving the environmental performance of shipyards.

- *A blueprint for an EU-material passport for waterborne transport assets classifying the ship circularity readiness level (CRL). In addition, a guideline for the passport maintenance throughout the ship life cycle backed by a business model for circularity and an appropriate regulatory regime in line with Regulation (EU) No. 1257/2013 on Ship Recycling (EU SRR), and coordinated with other ongoing Horizon 2020 / Horizon Europe projects.

- *Facilitate best practice design and construction to maximise the circularity of waterborne assets considering design, materials, capacity for re use.

- In close cooperation with ship owners and ports, demonstrate and testing of an innovative solution to provide auxiliary for ships moored and anchored at sea which can be deployable before 2030;

- Develop a solution which can be flexible in terms of area of application (i.e. can be re-deployed in other areas within a port, or be moved to other ports, both inland as well as sea ports where relevant);

- The solution will eliminate GHG and polluting emission from ships moored or at anchor;

- The solution will include a guideline on technical, operational and safety aspects;

- Assessment of the CAPEX and OPEX of the developed solution and optimization of the concept to increase the financial viability of the developed solution.

Scope: The environmental impact of ships throughout their operational life is governed by the IMO Energy Efficiency Design Index (EEDI, mandatory for new ships), the Ship Energy Efficiency Management Plan (SEEMP, all ships), as well as by IMO and EU GHG-targets for 2030 and 2050 respectively. In addition, the IMO Carbon Intensity Indicator (CII) for all cargo, RoPax and cruise vessels above 5,000 GT and trading internationally will come into effect in 2023. To ensure that ships at the end of their operational lives can be recycled and do not pose any unnecessary risks to human health, safety and to the environment, the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships was introduced in 2009. Furthermore the 2013 EU ship recycling regulation sets higher standards and requires that from 2019 ships must be recycled within an approved facility. Furthermore Green Passport and Green Passport EU may be assigned to ships by class societies which include an Inventory of on board Hazardous Materials (IHM).

However missing links are remaining in the assessment of the ship environmental value chain, in particular:

- A lack of data or industry standards describing the characteristics of the ship non-hazardous materials which give them value for recovery, recycling and re-use and a greater contribution to the "circular economy" in analogy with the cradle-to-cradle material passport in the building industry the concept of the 'material passport' is also being developed for shipping by multiple parties in mainly European countries.

- There is no environmental performance index and corresponding key performance indicators (KPI's) for shipyards addressing pollution to air, water and earth caused by shipbuilding and ship maintenance, repair, retrofit and dismantling processes, and for the environmental impact of these processes within the ships' life cycle.

- There is insufficient insight in alternative available high performance and clean production processes for floor technologies.

- There is no or insufficient insight in the shipyards' contribution, the ships design and non-hazardous materials towards the circular lifecycle of ships being built, repaired, maintained and retrofitted beyond the current IHM-passport.

- There is a lack of guidance concerning best practice to minimise the non-operational environmental impacts of shipping considering construction, materials, capacity to repair, design and capacity for recycling and re use, including difficult materials such as plastic composites. Such guidance could in future potentially form the basis of a recyclability labelling scheme.

The greening of shipyards towards measurable clean, efficient and low-energy consuming processes with low-to-zero pollution to air, water and earth as well as their contribution to ships' circularity will be the main challenges addressed by this topic.

Proposals are expected to address all of the following points:

- Develop and validate an environmental performance index with corresponding KPI's and determine a benchmark for shipyards through an investigation of shipyard floor processes, logistics and utilities i.e. energy use and emissions to air, water and earth.

- Identify the contribution of shipyards and ship design to the circular life cycle of ships in terms of reuse of components and materials within the context of shipyard processes, the shipbuilding value chain, capacity for repair and refit, end of life circularity and disposal value/cost. Considering also difficult materials such as reinforced plastics.

- Develop and validate a generic digital shipyard model encompassing shipyard floor technologies and logistic processes with the associated energy use and emissions, links to safety (eg ventilation to reduce indoor VOC's increasing energy consumption) and enabling to assess and benchmark the environmental performance of shipyards and the impact of clean floor technologies on shipyards' greening i.e. energy use, productivity, waste reduction, impact to air and water and the cost-efficiency of shipyards.

- Develop and validate a material circularity passport for maritime assets and identify the role of the manufacturing and design value chain stakeholders to apply best practices to increase circularity, reduce life cycle impacts and optimise end of life value. Foresee the compilation and maintenance of the passport over the ship lifecycle.

D5-3-13. Developing small, flexible, zero-emission and automated vessels to support shifting cargo from road to sustainable Waterborne Transport (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Technology Readiness Level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex B

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- Develop a small zero-emission automated vessel concepts which can support shifting cargo from road to water. The concept will take into account cargo types, water conditions (e.g. small waterways and shallow coastal waters and estuaries).
- Innovative automation approaches as well as tailored propulsion arrangements will be developed for small flexible and versatile vessel which are compatible with shallow water.
- The developed concepts will lead to reduced costs and stronger intra- and intermodal competitiveness of waterborne transport through integration of automated vessels and transhipment into automated transport chains, internet of things and possibly urban logistics.
- Business models that benefit from a high degree of digitalization, considering technical, safety, security and organizational aspects and when relevant smart on demand services.

- The flexible vessel concepts with emission-free propulsion systems will be tested and demonstrated in a relevant environment and through logistics modelling.

Scope: Waterborne transport is able to take over large volumes of freight from road transport, thereby reducing emissions and decongesting road infrastructure. There are large opportunities to increase waterborne freight, especially in coastal and inland or congested urban regions, by using intelligent approaches fully exploiting the potential of waterways. These potentials are underdeveloped, particularly within smaller waterways, lakes and estuaries and intra urban regions, and less developed ports which are not accessible with larger vessels.

Whilst projects addressing coastal transports and metropolitan inland transports are being undertaken, these remain at an early stage or are tailored to specific use cases which cannot be widely deployed. Emerging technologies for energy efficient and zero-emission propulsion systems and vessel automation can help exploit the potentials of small-sized waterborne transport but have to be adopted to the needs of such vessels. The increased utilization of small and sustainable units for waterborne transport is hindered by high operational costs and the need for additional transshipment.

Substantial cost savings in vessel operation and cargo handling need to be achieved in order to become more competitive with road transport. Hence, the degree of automation throughout the whole transport chain needs to be increased substantially.

A flexible, fully automated transport chain is considered as enabler and door-opener to connect new and previously not or poorly accessible regions to waterborne transport and to shift cargo from road to sustainable waterborne transport.

The mostly limited water depths of smaller waterways with confined conditions require intelligent solutions in terms of tailored vessel concepts. It is expected that a broad variety of concepts will be needed, each of them tailored to the regional requirements and the specifics of individual cargo types and load units, e.g., ISO containers, swap-bodies, unitized and palletized goods for urban transports. For instance, non-stackable swap bodies for unitized cargo in continental transports require different vessel designs and cargo handling systems than ISO containers in short sea shipping and hinterland distribution.

Decarbonization of propulsion systems is needed to address the challenges of climate change. Tailored solutions adjusted to the needs of small and sustainable vessels are missing. The automation solutions need to take into account unexpected recreational use of the waterways by citizens. The envisaged research shall develop solutions for small, versatile, low-water-adjusted and automated vessels with tailored zero-emission propulsion systems based on battery electrification or alternative climate neutral fuels. Developments can substantially profit from existing and emerging solutions as regards low-water designs, automation approaches, battery electrification, charging and propulsion systems. An uncrewed operation in multimodal logistics shall be envisaged through further development and integration of single automated functions into fully autonomous systems like e. g. navigation and vessel command, machinery surveillance, maintenance, berthing, cargo handling, transshipment etc..

In addition, self-organized or remotely controlled fleet-wide coordination of operations shall be addressed, along with an integration of the vessels into land-based digital logistics processes. This involves research activities regarding modular vessel design, (maritime) situational awareness systems, the application of digital communication technologies (e.g. vessel-port interaction) as well as security issues. Complementary, both the development of new business models including a high degree of digitalization and smart on-demand services and early approach of relevant regulatory and standardization bodies is regarded essential. Therefore, technical as well as organizational and regulatory aspects shall be incorporated. The identified solutions will be tested and demonstrated in a relevant environment and through logistics modelling.

D5-3-14. Towards the implementation of the inland navigation action programme with a focus on Green and Connected Inland Waterway Transport (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	CSA
Technology Readiness Level	NA

Expected Outcome

Targeted follow up coordination and support activities are needed in the Inland Waterways sector and in particular with respect to the implementation of the NAIADES III[71] actions after 2023 for greening and digitalisation and the leverage of the outcomes from related projects and to establish a bridge towards future research, innovation and implementation needs within inland waterways in coordination with the wider waterborne and logistics sectors.

Project outputs and results are expected to contribute to the following expected outcomes:

[71] Communication de la Commission: Future-proofing European inland waterway transport - NAIADES III action plan: Future-proofing European inland waterway transport - NAIADES III action plan (europa.eu)

- Promotion and development of the inland waterway sector for its greening and digitalisation objectives.
- Identify best practices and increase their take up and faster modernisation of the inland fleet.
- Build a viable financial engineering instruments to support investment in zero emissions vessels.
- Concrete European labelling system proposal on EU waterways
- Estimation of the potential modal shift to inland waterways transport with Impact of each Naiades III actions on modal shift.
- Provide a knowledge exchange, discussion and promotion platform for implementing Naiades III innovative actions
- Strengthen the coordination between national, EU and industrial research across waterborne transport and the wider logistics chain. Working together with the waterborne platform, assist in assessing current/future EU R&I programmes, implementation actions, technology assessments, forecasts and transfer of R&I solutions.
- Improve the environmental performance of inland waterways and contribute to future-proof infrastructure, compatible with digital and automation developments under a changing climate.

Scope: The EU Green Deal and NAIADES III challenges require a breakthrough Action Plan for the innovative system change from holistic perspective to achieve drastic emission reduction and modal shift targets. These elements leads to a change in the ownership structure and business models (e.g. energy as a service, leasing), intensive horizontal and vertical collaboration, vessels using (near) zero-emission technologies and energy carriers (e.g. batteries, fuel cell, synthetic fuels and clean combustion), standardised and modular hardware and ship design as well as advanced IT solutions for connected inland waterways transport, synchro-modal planning and smart shipping. Also the required infrastructure, regulations, incentives need to be addressed.

A dedicated Coordination and Support Action will act as European platform and catalyst by bringing together the required expertise, disciplines and stakeholders. Synergies and collaboration with other sectors and transport modes will be crucial elements.

The action will identify and analyse barriers and opportunities and will prepare the action plan for ground-breaking European wide implementation. A crucial element is to assess the Total Cost of Ownership and to underpin the financial resources needed in view of the next Multiannual Financial Framework, aiming for a dedicated financial instrument for funding automated zero emissions vessels with innovative public-private collaboration models for deployment[72].

A Digital Twin will be developed to support conclusions and recommendations on policy measures and regulations. The Digital Twin enables quantitatively simulating different scenarios and options to assess the contributions on modal share by the Naiades III measures and emission reductions and the impacts for the various stakeholders involved.

The action should focus on consolidating the Inland Waterways Transport (IWT) knowledge network and partnership, which was previously established with the support of H2020 and will end in 2023. In this respect, it should ensure a solid knowledge basis for the implementation of the actions of the NAIADES III programme related to Greening and Digitalisation. The coordination and support action will build on the results of previous work and will reflect the multi-disciplinary requirements and complexity of the subject, coordinating with the wider waterborne, land transport and logistics and land transport communities. It will identify the appropriate measures and define the necessary means and tools. In coordination with the Waterborne technology platform, the action will further develop a R&D roadmap by integrating all stakeholders and will also develop the implementation plan. Also in coordination with the Waterborne technology platform, the project will also monitor the inland navigation R&D projects and their impacts from relevant European programmes. The project will also identify barriers for the improvement of framework conditions to increase innovation in inland waterway transport. A particular focus will be to address the need to decarbonise and improve the environmental performance of inland waterway transport, particularly when operating close to urban areas, as well as on future-proof infrastructure, compatible with digital and automation developments under a changing climate.

This coordination and support action will ensure an active participation of key industrial stakeholders, the Waterborne Technology Platform, Member States administrations, industry associations and river commissions

Transport-related health and environment

[72] NAIADES III Annex I action 33 ”Facilitate the efforts of stakeholders and Member States to create a fund complementing EU and national financial instruments”, https://ec.europa.eu/transport/sites/default/files/com20210324-naiades.pdf and EP report P9_TA(2021)0367 “Towards future-proof inland waterway transport in Europe - European Parliament resolution of 14 September 2021 towards future-proof inland waterway transport in Europe (2021/2015(INI))” https://www.europarl.europa.eu/doceo/document/TA-9-2021-0367_EN.pdf

D5-4-1. Advanced transport emissions monitoring networks

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA

Expected outcome: Project results are expected to contribute to all of the following expected outcomes:

Supporting the Zero Pollution Action Plan and its monitoring strategy by:

- Monitoring pollutant and noise emissions of road vehicles to feed multiple real time systems and databases for air quality and environmental noise monitoring, anti-tampering enforcement, market surveillance and policy support at local, national and EU level.
- Monitoring pollutant and noise emissions around ports and airports, allowing for instance to monitor and enforce the respect of fuel use mandates in specific protection areas, correct noise abatement procedures, aircraft type limitations, etc.
- Establishing networks of at least three traffic air quality and noise stations in at least eight cities capable of measuring solid particle number (PN) and other emerging pollutants and GHGs in addition to the currently regulated ones (for which no funding is foreseen) and the impact of nature-based solutions (such as line trees along the streets, green facades in buildings, urban parks etc.) for mitigating them.
- Supporting local and national emissions and noise reduction plans (including dynamic ones based on smart traffic management systems, capable of influencing the behaviour of drivers and automated vehicles) by providing supporting real time data and integrating the impact of road, rail, port and airport traffic into the management strategy.
- Supporting health studies about the impact of ultrafine particles according to recent WHO guidance.
- Stimulate citizen awareness and engagement in the Zero Pollution strategy.

- Providing recommendations concerning the use of nature-based solutions for mitigating urban air and noise pollution.

<u>Scope:</u>

Transport emissions are a known cause of air and noise pollution in Europe, and therefore negative health impacts, particularly in urban environments. Road emissions play a significant part, but there can be important contributions by other transport sources if airports or ports or rail stations with significant traffic from diesel locomotives are within or close to the city boundaries. Moreover, construction machinery can provide important contributions to both emissions and noise where large building sites are present.

Long-term exposure to air pollutants and environmental noise from road traffic, railways and aircraft can lead to serious health effects, such as sleep disturbance, cardiovascular diseases, annoyance, cognitive impairment and mental health problems. Noise is another type of emission from such sources that can cause health impacts, in most cases also caused by combustion engines, but also by aerodynamics or tyre-road or wheel-rail interactions.

While some of these emissions are regulated, it has become apparent that the performance of propulsion and after treatment systems can change depending on use conditions or over time due to different causes (poor or even fraudulent design, tampering by the user, poor maintenance, catalyst degradation …) and therefore there is more and more interest to monitor these particle and noise emissions to the level of the individual vehicle and their cumulative effect at the city scale in order to provide a sound basis to understand the causes and to tackle, if needed, higher-than-expected emissions by enforcement or regulatory means.

The Flagship on the contribution of transport to pollution in the 2019 call has included several topics addressing the development of technologies to monitor some of these emissions, and it is now important to transfer these technologies to the field and to integrate them in networks capable of 24/7 unassisted operation and data management and reporting for enforcement and fleet monitoring by cities and national bodies, and where appropriate shared with EU level bodies.

The design, testing and demonstration of these applications will be developed in cooperation with the involved cities and authorities, to achieve the best use of monitoring data

Projects shall install monitoring stations around at least 5 ports and 5 airports, allowing for instance to monitor and enforce the respect of fuel use mandates, correct noise abatement procedures, aircraft type limitations, etc.

At the same time, recent WHO guidance [73] recognised the specific risks posed by nanoparticles and provided for the first time a quantification of what can be considered a low and a high concentration of particles in terms of numbers instead of mass. Guidance was also provided to widen the collection of data to ultrafine particles down to at least 10nm, in order

[73] https://apps.who.int/iris/handle/10665/345329

to allow the performance of epidemiological studies and, in the longer term, the establishment of new limit values.

Moreover, emerging pollutants and greenhouse gases are increasing due to the deployment of new technologies. Nitrous oxide, for instance, is both a very potent GHG and a neurotoxic with negative effects also on liver and kidneys, and is a by-product of several catalysts. Ammonia is also posing similar by-product issues, in particular for methane and SCR-equipped vehicles, by leading to high secondary particulate levels. Therefore monitoring these and other chemicals and their synergistic effects is becoming more and more important to inform policy decisions and provide data for modelling and emissions inventories.

A specific topic in the 2020 Green Deal call[74] foresaw the developments of measurement instruments and methodologies for ambient ultrafine particles and atmospheric particulate matter, their sizes, constituents, source contributions and gaseous precursors. The wider deployment of the results on a cross European base, encompassing as many as possible different locations in terms of urban morphology and meteorological and pollution conditions is paramount for the validation of the system and to establish an EU-wide network.

In consideration of the above, proposals shall address all the aforementioned aspects and issues in order to achieve the expected outcomes.

D5-4-2. Assessment of air pollutant emissions from low-carbon fuels in the heavy-duty and maritime sectors

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

<u>Expected outcome:</u> Project results are expected to contribute to all of the following expected outcomes:

[74] [74] https://cordis.europa.eu/programme/id/H2020_LC-GD-9-1-2020 and projects https://cordis.europa.eu/project/id/101037319 and https://cordis.europa.eu/project/id/101036245

- The air pollutant emissions from combustion-based heavy duty vehicles, aircraft and ships using alternative fuels, with a broad coverage of existing (at least in advanced prototype form) powertrains and exhaust after treatment technologies, are measured and characterised.
- Emerging pollutants resulting from the use of novel low-carbon fuels are identified and quantified.
- Following recent WHO advice, number concentrations of ultrafine particle emissions down to at least 10nm are also measured, as well as the characterisation of chemical species absorbed on such particles, in particular carcinogenic compounds like aldehydes, PAHs and NPAHs.
- Air pollution exposure projections based on plausible technological trajectories are produced, up to the year 2050.
- Technology packages to mitigate the emerging forms of pollution are proposed and projections updated accordingly.
- Reliable scientific data to guide future policy and technology choices following the "do no significant harm" principle are provided

Scope:

Low-carbon fuels proposed for use in the next decade can be covered, but those which have already been demonstrated in real applications or are foreseen to gain market share according to the projections made in the context of the 'Fit for 55' package must be prioritised.

A complete polluting emissions speciation shall be performed in different working conditions encountered in real use. Therefore, pollutants to be quantified should go beyond the list of currently regulated ones.

Since accessing ships and aircraft for testing is not straightforward, and no fuel or engine development work shall be funded in the proposals, cooperation with existing projects where such fuels are tested is expected.

A study of possible mitigation actions should focus on any new pollutants that have a high toxicity, a high global warming potential, or both.

The potential from upstream emissions and of secondary pollutants formation in the atmosphere deriving from the new emissions should also be considered and quantified, and any trade-offs between GHG effects over the next 20-year period, health and other environmental impacts identified and assessed.

The projects may assess impacts on human health.

Destination – Safe, Resilient Transport and Smart Mobility services for passengers and goods

This Destination includes activities addressing safe and smart mobility services for passengers and goods.

Europe needs to manage the transformation of supply-based transport into safe, resilient and sustainable transport and demand-driven, smart mobility services for passengers and goods. Suitable research and innovation will enable significant safety, environmental, economic and social benefits by reducing accidents caused by human error, decreasing traffic congestion, reducing energy consumption and emissions of vehicles, increasing efficiency and productivity of freight transport operations. To succeed in this transformation, Europe's ageing (and not always sustainable) transport infrastructure needs to be prepared for enabling cleaner and smarter operations.

Europe needs also to maintain a high-level of transport safety for its citizens. Resilience should be built in the transport systems to prevent, mitigate and recover from disruptions. Research and innovation will underpin the three safety pillars: technologies, regulations and human factors.

This Destination contributes to the following Strategic Plan's **Key Strategic Orientations (KSO)**:

- *C: Making Europe the first digitally enabled circular, climate-neutral and sustainable economy through the transformation of its mobility, energy, construction and production systems;*
- *A: Promoting an open strategic autonomy*[75] *by leading the development of key digital, enabling and emerging technologies, sectors and value chains to accelerate and steer the digital and green transitions through human-centred technologies and innovations.*

It covers the following **impact areas**:

- Industrial leadership in key and emerging technologies that work for people;
- Smart and sustainable transport.

The **expected impact**, in line with the Strategic Plan, is to contribute to *"Safe, seamless, smart, inclusive, resilient and sustainable mobility systems for people and goods thanks to user-centric technologies and services including digital technologies and advanced satellite navigation services"*, notably through:

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[75] *'Open strategic autonomy' refers to the term 'strategic autonomy while preserving an open economy', as reflected in the conclusions of the European Council 1 – 2 October 2020.*

a. Accelerating the implementation of innovative **connected, cooperative and automated mobility (CCAM)** technologies and systems for passengers and goods (more detailed information below).

b. Further developing a **multimodal transport system** through sustainable and smart long-haul and urban freight transport and **logistics**, upgraded and resilient physical and digital **infrastructures** for smarter vehicles and operations, for optimised system-wide network efficiency (more detailed information below).

c. Drastically decreasing the number of **transport accidents, incidents and fatalities** towards the EU's long-term goal of moving close to zero fatalities and serious injuries by 2050 even in road transportation (Vision Zero) and increase the **resilience** of transport systems (more detailed information below).

Connected, Cooperative and Automated Mobility (CCAM)

Main expected impacts:

1. Seamless, affordable and user oriented CCAM based solutions for mobility and goods deliveries for all and high public acceptance of these solutions.
2. Validated safety and security, improved robustness and resilience of CCAM technologies and systems.
3. Vehicle technologies and solutions which optimise the on-board and off-board experience in terms of well-being, security and privacy.
4. Comprehensive set of verification, validation and rating procedures of CCAM systems
5. Secure and trustworthy interaction between road users, CCAM and "conventional" vehicles, infrastructure and services to achieve safer and more efficient transport flows (people and goods) and better use of infrastructure capacity.
6. Clear understanding of user needs and societal aspects of CCAM, in particular with regard to ethics and impacts on employment and skills development.
7. European framework for collection and exchange of CCAM data and best practices

Multimodal and sustainable transport systems for passengers and goods

Main expected impacts:

1. Upgraded and resilient physical and digital infrastructures for clean, accessible and affordable multimodal mobility.
2. Sustainable and smart long-haul and regional (including links to urban) freight transport and logistics, through increased efficiency and improved interconnectivity.

3. Reduced external costs (e.g. congestion, traffic jams, emissions, air and noise pollution, road collisions) of passenger mobility and freight transport, as well as optimised system-wide network efficiency and resilience.

4. Enhanced local and/or regional capacity for governance and innovation in passenger mobility and freight transport.

Safety and resilience - per mode and across all transport modes

Main expected impacts:

Safety in Urban Areas / Road Transport Safety

1. Drastic reduction in serious injuries and fatalities in road crashes by 2030 and establishing a framework to improve traffic safety culture in the EU.

2. Improved reliability and performance of systems that aim to anticipate and minimize safety risks, avoiding risks and collisions, and reducing long term consequences of road crashes.

3. Minimising the effects of disruptive changes on transport safety and improving smart care and rescue measures.

4. Better infrastructure safety on urban and secondary rural roads throughout a combination of adaptable monitoring and maintenance solutions.

5. Ensuring the right level of driver vigilance with new human technology interfaces.

Waterborne Safety and Resilience

6. Comprehensive understanding of the safety risks associated with emerging alternative fuels and energy systems.

7. Digitalization, Internet of Things, and sensors are transforming the ship's systems design; system and system of systems approach to exploit the potential of these technologies in a safe and secure way.

Aviation Safety and Resilience

8. Anticipate emergence of new threats that could generate potential accidents and incidents (short, medium, and long term).

9. Ensure safety through aviation transformation (from green/digital technologies uptake up to independent certification).

Connected, Cooperative and Automated Mobility (CCAM)

D6-1-1. Centralized, reliable, cyber-secure & upgradable in-vehicle electronic control architectures for CCAM connected to the cloud-edge continuum (2024, RIA, TRL 5)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex B.

Expected Outcome:

Project results are expected to contribute to all of the following outcomes:

- New, centralized, reliable, cyber-secure & upgradable in-vehicle electronic control architectures for CCAM based on the application of co-designed hardware, software and big data flows in combination with over-the-air updates.
- Widespread deployment of level 4 automation in road vehicles in growing Operational Design Domains (ODDs).
- Safe operation of Connected and Automated Driving (CAD) functions e.g. regarding vulnerable road users and ODD transitions through system agility, experience-based decision making and access to cloud intelligence.
- Paradigm shift from human-based and component-supported vehicle control to a more integrated, resource efficient and reliable system for the control of CCAM systems.
- Strengthened cooperation of European OEMs and suppliers to co-design a standard cybersecure electronic architecture layout with harmonized interfaces.

Scope:

Since current on-board electronic systems are assembled from various controllers in a piecemeal fashion, they are not suitable for the complex, combined performance requirements of advanced levels of CCAM applications in terms of bandwidths, latency, flexibility, fail safety and cyber security. Therefore, a complete redesign of the in-vehicle control architecture is needed, combining innovations at hardware, software and data levels in the vehicle and in connection with its edge-cloud continuity. It shall build on a centralized e.g. zonal or domain based layout using distributed high performance computing for connecting sensing and actuation systems with software updates over the air, big data flows and AI at the edge, resulting in a novel and upgradable electronic in-vehicle control scheme for safe and efficient automated driving functions and tele-operations.

Important building blocks for the in-vehicle control architecture include sensors and sensor data fusion for environment perception with AI "at the edge", using on-board high performance computers and generic hard- and software including cyber secure components.

At the same time, the following needs to be enabled by the new control architecture and its context aware building blocks:

- Reliable, low-latency and high-bandwidth data communication for automated driving systems control to safeguard against cyber-attacks, malfunctions and malicious interactions.
- Systemic functionality gains in upgradability, efficiency, modularity, compatibility, scalability, fail-operation, reliability and redundancy.
- Definition of safety and security targets, open-source standard layouts and harmonised validation methods.

D6-1-2. User-centric development of vehicle technologies & services to optimise the on-board experience and ensure inclusiveness (2023, RIA, TRL 5)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex B.

Expected Outcome:

Project results are expected to contribute to all of the following outcomes:

- Advanced vehicle technologies and solutions which optimise usability, perception and experience on-board, and when boarding/off-boarding, in terms of security, privacy, well-being, health and assistance.
- Enhanced inclusiveness and trust in the interaction between users and new automated modes of road transport and mobility services in the transition from human-driven to automated vehicles.
- Safety and security of vehicle occupants in all circumstances even when the vehicle is driverless by helping to prevent dangerous and inconvenient situations also when boarding/off-boarding.
- Strengthened cooperation between users, vehicle manufacturers, suppliers, researchers and other stakeholders to co-design vehicles with solutions that optimise the on-board experience.
- Full exploitation of the new opportunities offered by automated vehicles to provide user-centric and inclusive mobility for all.

Scope:

In the transition from human-driven to automated vehicles, optimizing the on-board experience and overall satisfaction of users is paramount for high social acceptance and widespread adoption of CCAM-based solutions for mobility. A rapid evolution of the interaction between users and the vehicle is needed in terms of inclusiveness and trust with respect to new automated modes of road transport and mobility services. This must be ensured through the development and validation of advanced vehicle technologies and solutions which serve to optimize the usability, perception and experience on-board, and when boarding/off-boarding. Such solutions must be designed holistically by adopting a universal design approach from an inclusive, user-centric perspective. All users (irrespective of gender, age, disabilities, etc.) will demand vehicles which enable engagement in relaxing, social or work-related activities within a space designed for health and well-being, providing digital continuity and ensuring privacy for social interaction. Hence a wide range of different user groups must be involved since the early stages of development and their specific needs understood, to develop technologies and solutions for individual and shared automated vehicles and that meet the demands of all.

To achieve these objectives, it is expected that activities will focus on the development and validation of a range of new, advanced technologies and services that are also fully aligned with safety requirements, including:

- Perception-focused solutions and features (e.g. temperature, lighting, sound/acoustics, vibration, seating, posture,...), aimed at enhancing the sense of safety, well-being and privacy, while eliminating stress, including also personalisation, taking into account specific needs of individuals from diverse user groups (including the elderly or disabled);

- Alternative, flexible and automated interior configurations to better suit occupants' needs;
- Adaptive systems that can also transfer preferred personal settings between vehicles to increase the user acceptance of shared vehicles;
- Solutions to tackle motion sickness;
- Introduction of new mobility services based on users heterogeneous requirements and preferences of different target groups;
- Solutions to observe also outside the vehicle which can support reducing the potential for vehicle misuse or risky/dangerous situations (e.g. assaults, vandalism, thefts, etc.)
- Evaluation of the impact of advanced vehicle technologies and services in terms of on-board experience and inclusiveness in comparison to conventional solutions.

The topic requires effective contribution of Social Sciences and Humanities (SSH) disciplines and involvement of SSH experts.

D6-1-3. Generation of scenarios for development, training, virtual testing and validation of CCAM systems (2023, RIA, TRL 5)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex B.

<u>Expected Outcome:</u>

Project results are expected to contribute to all of the following expected outcomes:

- Accelerated AI development and training and improved validation methodologies of CCAM systems enabled by real and synthetic test scenarios, with the widest possible coverage of traffic situations CCAM systems can encounter on European roads.

- Tools for edge case identification and capturing and automated processing chain generating such scenarios from real traffic data and/or from traffic simulations.

Scope:

Higher levels of CCAM require validation methodologies making use of virtual testing. This is necessary as conventional testing and validation approaches would require driving hundreds of millions of test kilometres. Relevant test scenarios need to be extracted from real traffic data and in future potentially also from advanced traffic simulations. To maximise the outcome, proposed actions shall:

- Demonstrate upfront commitment from key stakeholders to help build such scenarios, notably by providing the raw data needed to extract them from, as well as dedicating resources to ensure the scenarios are developed in a manner that maximises their utility and successful integration of their future (virtual) development and testing processes.

- Share these scenarios in an openly accessible EU wide database, which shall be established by a project to be funded under HORIZON-CL5-2021-D6-01-02.

Actions shall develop an automated processing chain with full traceability which will accelerate the extraction of scenarios from driving data collected during physical CCAM testing campaigns. This transformation will focus on detecting edge cases - the relatively rare, but particularly challenging situations - and include plausibility checks. The processing chain must comply with the FAIR principles and should be agnostic to sensor technologies, data providers and traffic environments. In particular, it should have standardised, open interfaces to enable the efficient and seamless use of data from different sources.

This will be complemented by the scenarios made available by national and other EU-funded projects (incl. from large-scale demonstrations of CCAM). In addition, the potential of complementing scenarios extracted from real traffic with scenarios from advanced traffic simulations shall be explored.

The proposed actions shall address the following aspects:

- AI based tools to transform raw driving data into reliable, plausibility-proofed data as well as tools for automatic scenario identification and extraction from that data, focusing on the detection of edge cases

- Generation of variations of scenarios (starting from those based on real traffic data) with a focus on extending ODDs (e.g. adverse weather conditions)

- Integration of the above in an automatic processing chain with open interfaces including the data management through the whole process

- Demonstration of the suitability of the processing chain by processing high-quality big traffic data (e.g. vehicle- and infrastructure-based) in order to gain comprehensive knowledge on relevant training, testing and validation scenarios with
    - o high geographic coverage including cross-border areas;
    - o high seasonal coverage including adverse environmental conditions (e.g. extreme weather conditions) and their synchronized recording; and
    - o coverage of complex traffic environments including the interaction with other road users (e.g. pedestrians, bicyclists, users of personal mobility devices);
    - o Data from other projects, including from large-scale demonstrations of CCAM, should be used as much as possible.
- Feeding the resulting scenarios in an openly accessible dynamic scenario database, which can be used for the development, training, virtual testing and validation of CCAM systems.
- Exploring the potential of complementing raw data from real traffic with data from highly detailed traffic simulations, including the use of AI to generate edge cases and other adversarial driving conditions in such simulations.

The research will require due consideration of cyber security and GDPR issues.

Proposed actions are expected to develop recommendations for harmonisation and standardisation and to feed into on-going discussions regarding EU type vehicle approval rules as well as in the framework of the UNECE.

D6-1-4. Scenario-based safety assurance of CCAM and related HMI in a dynamically evolving transport system (2024, RIA, TRL 5)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology	Activities are expected to achieve TRL 5 by the end of the project – see

Readiness Level	General Annex B.

<u>Expected Outcome:</u>

Project results are expected to contribute to all of the following expected outcomes:

- A scenario-based safety assurance methodology that incorporates the assessment of the full human-machine interaction (incl. transfer of control from CCAM to human driver and back) over all driving phases to support the (market?) introduction of CCAM systems.
- A solid in-service safety assessment system, to assure continuous safety despite system changes, e.g., due to software updates and data exchanges between vehicles and the infrastructure.
- A methodology that allows the use of fast developing technological innovations in the CCAM system's functionality, such as AI.

<u>Scope:</u>

To ensure safety of CCAM, it is essential that vehicles are not only safe during the (first) type approval, but during their complete lifetime in a fast-changing road transport system. Changes can result from the evolution of the CCAM system itself, for example, as a result of increasing connectivity using V2X communication, the use of AI-based systems, and (over-the-air OTA) software updates. The traffic system in which the CCAM systems are being deployed is changing at a rapid pace as well, with an increased market share of vehicles with higher levels of automation, new (personal) mobility devices and autonomous mobility robots (e.g., for package delivery).

At the same time, the way CCAM systems interact with humans in traffic is changing. Until full automation in transport is reached, the human driver will keep on playing an essential role. Also, the interaction with other road users will change supported by technologies that allows a CCAM-system to communicate its intentions to the other road users.

As a consequence of these innovations and developments, safe deployment of CCAM systems needs an extension to the safety validation procedures and certification schemes, taking advanced human-machine interaction and a continuous in-service monitoring approach into account. Due to the many different scenarios and variations that can occur realistically and that consequently need to be tested, it should be possible that a large part of the assessment is performed in a virtual simulation environment.

The proposed actions shall address the following aspects:

- Developing a methodology for scenario-based safety assurance of AI-based CCAM functions. Trustworthiness of the AI-algorithms depends on how well the system responds to scenarios in its Operational Design Domain (ODD) – specificity and how the systems respond in case it ends-up outside its ODD – robustness. Consequently, methods need to be developed on the use of scenarios to describe the ODD of AI-based systems.

- Connectivity. Developing validation procedures for CCAM systems which rely on V2X for safety-critical functions i.e., the inclusion of the connectivity context. Ensuring aspects of reliability, trustworthiness and cyber-security with respect to V2X is essential.
- Continuous Safety Assurance approach. Developing an approach for a continuous safety validation methodology, to monitor the safety state of deployed CCAM systems in operation (real traffic) during its service life, following type approval. Performance metrics need to be established for the reliability of the monitored data, and indicators for the safety state need to be determined and standardized. Requirements to the monitoring system need to be established and standardization is needed regarding the exchange of data and safety performance indicators with service organizations and authorities.
- Validating the virtual approach. Developing tools that ensure the relevant degree of detail and the appropriate representation of the behaviour of other road users (incl. VRU: pedestrians/bicyclists) in virtual scenario-based testing. This includes methods to deal with perception, localization, and world modelling errors in the validation procedures.
- Human Machine Interaction. Developing safety assurance methodology that incorporates the assessment of Human Machine Interaction (both driver-vehicle and vehicle-road user) concepts for higher levels of automation (conformity checks + test set-ups with suitable metrics) ensuring safe communication between driver and vehicle and between vehicle and road user, given the large variations in driver and road user ability and behaviour (inclusiveness, cultural, etc.).

Proposed actions are expected to develop recommendations for harmonisation and standardisation and to feed into on-going discussions regarding EU type vehicle approval rules as well as in the framework of the UNECE.

Actions should be based on the outcomes of research funded under HORIZON-CL5-2021-D6-01-02

D6-1-5. Infrastructure-enabled solutions (e.g. Digital Twins) for improving the continuity or extension of Operational Design Domains (ODDs) (2023, IA, TRL 6-7)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex B.

Expected Outcomes:

Project results are expected to contribute to all of the following outcomes:

- Infrastructure-enabled solutions improving the continuity of or extending the Operational Design Domains (ODDs), supporting the real time knowledge about conditions in the "electronic horizon", the centrimetric accuracy of the positioning signal, the ability of CCAM enabled vehicles to navigate through road works and incident sites.
- System, data and service architectures for Digital Twins for road traffic developed and feasibility proven, incl. technology requirements, coherence with proven physical and digital infrastructure support concepts, input to standardisation, also legal, trust and data security aspects as well as business and governance models (incl. organisational processes and right of use of data) for Digital Twins.
- Advanced cooperation of CCAM actors in a robust and functionally safe manner for reasons of ODD continuity/extension, enhancing the readiness of CCAM services and their future extendibility.

Scope:

Operational Design Domains (ODDs) of automated vehicle functions are currently limited (e.g. motorways up to 60 km/h). Infrastructure enabled or infrastructure supported solutions can greatly help automated vehicles to overcome the limitation and fragmentation of ODDs. A number of Horizon 2020 projects has delivered promising concepts how infrastructure and vehicles can work together (e.g. Infrastructure Support for Automated Driving) and projects addressing the first Horizon Europe calls of the CCAM Partnership (most notably HORIZON-CL5-2021-D6-01-03: Physical and Digital Infrastructure (PDI), connectivity and cooperation enabling and supporting CCAM) are expected to expand on this fruitful ground.[76]

[76] CCAM Partnership, Strategic Research and Innovation Agenda 2021-2027, December 2021, https://www.ccam.eu/, Lessons Learned from completed projects: https://connectedautomateddriving.eu/ projects/lessons-learned/, Horizon Europe Work Programme 2021-2022, Climate, Energy and Mobility, *European Commission Decision C(2021)4200 of 15 June 2021.*

The call topic is focused on the individual vehicle perspective and the infrastructure support towards larger ODDs.[77] Proposed R&I actions addressing this topic are expected to contribute to improving the continuity of ODDs (Level 3 according to SAE J 3016) or to extend ODDs (Level 4).

Proposed actions for this topic shall address all the following aspects:

- Improve the availability of real-time information on conditions beyond the reach of vehicle on-board sensors. Digital twins are regarded as a means to improve the real-time availability of information, especially on information that stems from road authorities and road operators. Digital Twins also serve as a data source for prescriptive analytics and simulation environments, in order to improve the efficiency of (virtual) testing. Moreover, Digital Twins play an important role for asset management.

- Remove the discontinuity of the GNSS positioning signal in challenging road environments such as urban canyons and canopies, mountainous areas and northern latitudes. Actions shall develop approaches to improve the robustness and reliability of the positioning information by landmarks, modules, new procedures and redundancy processes etc.

- Develop novel solutions for the management of and navigation through road works and incident sites for CCAM enabled vehicles, making such high-risk zones much safer for road users (including vulnerable road users) but also for road workers and rescue organization personnel. Advancing CCAM from information only to services with automated actions requires cooperation in higher classes (according to SAE J 3216). Aspects such as communication in a functionally safe and secure manner, transfer learning and distributed data processing as well as tools and enablers improving the vehicles' capabilities of coping with infrastructure imperfections (such as sub-standard infrastructure maintenance) must be addressed. Furthermore, harmonised local traffic management measures at road works and incident sites to support their safe navigation could also be addressed.

R&I actions shall advance the infrastructure-enabled solutions for ODD continuity/extension to TRL 6/7 on the way towards (pre-) deployment as an important contribution to large-scale demonstration actions. EU-wide/global harmonisation is key in this R&I action, enabling broad uptake of services in the common single market and paving the way towards coordinated deployment of necessary infrastructure support for CCAM. Potential needs for standardisation or input for future regulatory action should be developed.

The R&I actions will also involve social innovation embedding the maturing technology in an appropriate societal context (addressing e.g. legal, trust and data security aspects (possibly

[77] The scope of this call is complemented by the system point of view of call HORIZON-CL5-2024-D6-01-0x: Orchestrate Traffic Management for fleets, individual vehicles and Vulnerable Road Users (including tools such as digital traffic rules) for enhancing the readiness of CCAM services (CCAM Partnership).

incl. certification), business and governance models (incl. organisational processes), all aiming at co-designing, co-investing, jointly implementing and managing CCAM services. The topic hence requires effective contribution of Social Sciences and Humanities (SSH) disciplines and involvement of SSH experts.

In order to achieve the expected outcomes, international cooperation is advised for all projects of this topic.

D6-1-6. Orchestrate TM for Fleets and individual Vehicles and VRUs (including tools such as Digital traffic rules) for enhancing the readiness of CCAM services (2024, IA, TRL 6-7)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex B.

Expected Outcomes:

Project results are expected to contribute to all of the following outcomes:

- Evidence on how automated driving can contribute to the development of a more efficient and sustainable mobility ecosystem and in particular how the integration of CCAM services in the mobility ecosystem can be facilitated by essential elements in traffic management.
- System approach towards traffic management that integrates the operations and needs of road network users within the mobility ecosystem.
- Better orchestration of traffic management through the integration of automated systems including public transport, demand management, fleet and traffic management, and digital traffic rules and business models.

- Framework of unambiguous and objective digital driving rules (digital versions of national driving handbooks, traffic orders, mandatory traffic management measures such as variable speed limits, etc.) and inventory of traffic regulation challenges across the EU MS and their traffic culture.

- Optimization and planning methods for fleet & traffic managements including integration with public transport.

Scope:

This topic aims at addressing the lack of a harmonised set of requirements for an overall traffic management system for CCAM and will develop and demonstrate tools that can facilitate its proper orchestration. These tools include reliable and robust modelling tools for the coordination of mixed automated and non-automated mobility covering uncertain technological developments & performances, services & business cases. Tools shall take into account ad-hoc & manoeuvres coordination (the SAE cooperation classes), efficient route guidance and capacity aware demand management.

The system point of view scope of this call is complemented by the individual vehicle perspective of call HORIZON-CL5-2023-D6-01-0x: Infrastructure-enabled solutions (e.g. Digital Twins) for improving the continuity or extension of Operational Design Domains (ODDs) (CCAM Partnership).

Proposed actions for this topic shall address all the following aspects:

- Develop processes ensuring user trust and sufficient data quality.

- Identify workable governance/business models needed for the orchestration of traffic management for fleets, individual vehicles and for VRUs.

- Develop unambiguous and objective digital driving rules (digital versions of national driving handbooks, traffic orders, mandatory traffic management measures, etc.). This includes the compilation of a digital traffic rules catalogue and metrics related to traffic rules compliance, and impact on other driving measures (congestion, journey times, etc.).

- Identify problems in traffic regulation and harmonise of traffic rules across the Member States and their traffic cultures. In order to resolve ambiguities and eliminate current subjectivity in the EU MS national codes, actions will define a digital driving license (as related to the digital driving license for the vehicle system currently discussed at the UNECE).

- Demonstrate orchestration of traffic management (governance and organizational models) in real-time CCAM traffic conditions.

- Implement measurements for tracing the capacity demand and manoeuvres coordination based on ITS services and assessed their impacts on real traffic.

Proposed actions are expected to build upon the results of HORIZON-CL5-2022-D6-01-04: Integrate CCAM services in fleet and traffic management systems (CCAM Partnership)[78]. The results of SOCRATES 2.0 project [79] and TM 2.0 concept [80] on smart routing are also complementing this Call.

The progress of international work on standardization (METR) must be taken into account to enhance the readiness of CCAM services.

In order to achieve the expected outcomes, international cooperation is advised.

D6-1-7. Hybrid AI for advanced and collective perception and decision making for CCAM applications (2024, RIA, TRL 5)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex B.

Expected outcomes:

Project results are expected to contribute to all of the following expected outcomes:

- Concepts and tools based on Artificial Intelligence (AI) used for advanced situational awareness, decision making and triggering of actions for time critical and safety relevant

[78] CCAM Partnership, Strategic Research and Innovation Agenda 2021-2027, December 2021, https://www.ccam.eu/, Horizon Europe Work Programme 2021-2022, Climate, Energy and Mobility, *European Commission Decision C(2021)4200 of 15 June 2021* (https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-8-climate-energy-and-mobility_horizon-2021-2022_en.pdf)

[79] **Connecting Europe Facility (CEF) 2016-EU-TM-0148-S 2017 (https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/2016-eu-tm-0148-s)**

[80] TM 2.0 Innovation Platform on interactive traffic management https://tm20.org/

CCAM applications. CCAM solutions will evolve from reactive into predictive system state awareness (including driver state and user diversity), decision making and actuation, enhancing road safety.

- Approaches for resilient collective situational awareness, including self-organised bottom-up models of collective behaviour based on the change/modelling of individual interactions
- A clear understanding of capabilities, limitations and potential conflicts of AI based systems for CCAM, while addressing ethical aspects and user needs.
- Increased user acceptance and societal benefit, from an early stage, based on explainable, trustworthy and human-centric AI. Interactions with AI-based vehicles should be understandable, human-like and reflect human psychological capabilities.

Scope:

Today's mobility landscape is rapidly changing due to a recent boom in the detection of advanced and/or complex urban scenarios that add new challenges to the development of CCAM technologies. These novel scenarios require the establishment of new urban traffic regimes and cultures, such as restricted zones, shared zones, low traffic neighbourhoods, cycle-streets, school traffic zones, which should all be taken into account when designing and developing CCAM solutions.

To integrate and tackle complex traffic scenarios, CCAM technologies will require highly advanced decision-making based on enhanced situational awareness – the stage beyond on-board perception – incorporating information from multiple sources and including interpretation for the aggregation of this information. This enhanced situational awareness should take into account the state of the vehicle, the state of the driver and the state of the road user environment. It also involves tracking other road users' behaviour and generating predictions on a short horizon, which can be based on the input from advanced behavioural models.

The use of multiple sources (sensors, maps, infrastructure, other road users, and localisation systems) and the sharing of the overall situational awareness and related intentions of the vehicle and that of its direct environment will be an important building block towards collaborative situational awareness. This can create a larger time window in safety critical situations and generate benefits for the overarching mobility system, which include efficient traffic management and improved traffic flow as it incorporates situation prediction capabilities and environmental benefits (which could include e.g. smart charging strategies down the line).

In order to reach collective situational awareness and boost its capabilities, a Hybrid Intelligence (HI) approach will be necessary. Hybrid Intelligence is the process of developing and mobilising Artificial Intelligence (AI) to expand on human intelligence and expertise, thereby ensuring human-like control of CCAM automated operations. Indeed, applying a HI approach will allow CCAM technologies to integrate human expertise and intentionality into its decision-making in order to generate meaningful and appropriate actions that are aligned with ethical, legal and societal values. This will be essential to foster user acceptance, trust and user adoption.

Proposed R&I actions shall address following aspects:

- Methods to establish collective situational awareness of CCAM applications that are resilient to faulty sources, thereby ensuring safe operations. Guidance for failsafe designs should be developed.
- Hybrid approaches to enable human-like control of autonomous systems, thus combining system and domain knowledge. Tooling needed to deliver situational awareness information in a structured way, based on multiple sources e.g. sensor fusion, mapping, localisation. This thorough way of describing complex situations has to be established real-time. Ethical goal functions should be included. Work should be:
    - Based on at least perception systems, sensor fusion, high-level world models/maps, vehicle positioning information. Guidance on common reference systems for positioning and time for synchronisation should be included in order to secure robustness and traceability.
    - Based on relationships between the vehicle and forecasted intentions of other road users (e.g. a pedestrian crossing the street at a zebra crossing), as such including spatial temporal relation of elements in the driving-situation.
- Methods to embed such hybrid approaches in the action chain (from basic perception to driving functions) to allow for seamless operation and real time decision making. Liability should be considered, especially for transitions of control.

D6-1-8. Integrating European diversity in the design, development and implementation of CCAM solutions to support mobility equity (2023, RIA)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions

Technology Readiness Level	

Expected outcomes:

Projects results are expected to contribute to all of the following outcomes:

- Increased knowledge about the influence of geographical and cultural dimensions on the societal acceptance, uptake and use of CCAM.
- Principles, criteria and recommendations for CCAM service and system developers and implementers (including local decision-makers and policymakers) that foster the integration of geographical and cultural factors in the planning, design, development and implementation of CCAM solutions through proactive and corrective measures.
- A strategy for fair and just deployment of CCAM systems and services, adapted to local contexts and cultures, leading to enhanced acceptance and willingness to use CCAM in Europe, thereby contributing to CCAM's expected societal benefits.
- Increased transferability of CCAM solutions and experiences through the structured transfer of knowledge and lessons learnt between Europe's cities, regions and projects.

Scope

Research on the societal implications and deployment of CCAM systems and services has mostly been "geography- and culture-agnostic", focusing instead on mobility behaviours at demographic level and prioritising factors like age and gender. However, European countries encompass multiple cultures, historical heritages and public policy approaches (e.g. on climate change, digitalization, and road safety) which may influence the uptake and use of CCAM. These cultural, geographical and policy diversities need to be integrated into the design, development and deployment of CCAM solutions. Such diversities can include infrastructure (certain regions have dedicated lanes for alternative mobility solutions, strong bike cultures), specific geographical dispositions (mountains, harsh weather conditions leading to car-captivity or a centralisation of mobility services), or cultural norms and working conditions. Furthermore, the acceptance of innovative services and solutions can also vary across regions (the Netherlands have an inclination towards embracing innovation and new technologies[81], Germany has a strong, cultural attachment to the notion of privacy, which can be illustrated by higher degree of caution concerning the presence of CCTVs in public spaces, compared to other European countries). In addition, there are also regional regulatory, policy and governance structures that influence the development and implementation of CCAM (e.g. some regions have a strong and historic cooperation culture with stakeholders

[81] See KPMG's 2020 Autonomous Vehicles Readiness Index where the Netherlands ranked second behind Singapore.

from the automotive sector, which can have an impact on the region's willingness to test and plan for CCAM solutions[82]).

Adapting and building on these European differences and similarities will ensure a more tailored, resilient and sustainable match between CCAM solutions, people and societal needs, thereby leading to higher public acceptance and societal benefits. Proposals under this topic will therefore provide a geographical and cultural understanding of CCAM uptake and use, with the aim of contributing to a more integrated and diverse approach to the design, development and implementation of CCAM supporting mobility equity.

In order to successfully address the expected outcomes, projects must:

- Evaluate how cultural and regional particularities have led to different transport infrastructure, societal settings, travel needs and behaviours.
- Develop methodologies that take into account the impact of cultural and regional diversities on attitudes, demand, uptake, and implementation, early in the design and development phase of CCAM services and solutions. In particular, these methodologies should be based on:
    1. Existing studies and pilots that have investigated isolated diversity aspects in automated mobility contexts.
    2. A systems perspective, with specific attention on the impact of CCAM on digital equity (e.g. methods for service payment and information, access to CCAM services, avoiding the negative equity effects of CCAM services without a human driver).
- Develop principles, criteria and recommendations for the developers and implementers of CCAM systems and services (including local decision-makers and policymakers) that foster the integration of geographical and cultural factors in the planning, design, development and implementation of CCAM through proactive and corrective measures.
- Propose indicators and approaches to enable a fair integration of cultural and regional factors in CCAM impact evaluation frameworks to better reflect the need for CCAM to support mobility equity.
- Develop mechanisms to transfer knowledge, e.g. maps, matrices or other instruments, to capture patterns and recurring typologies of settlements, infrastructure and travel indicators in Europe to foster dissemination of CCAM solutions. Include documentation of lessons learnt and approaches for an iterative and long-term evolution and update of the mechanism (until 2030).

[82] See Gothenburg's strategic plan for transport innovation in electrification, digitalisation and automation https://www4.goteborg.se/prod/Intraservice/Namndhandlingar/SamrumPortal.nsf/0DB617C7ACDB6EB5C1258531002E7459/$File/Bilaga%201.pdf?OpenElement

- Propose a pilot activity in at least three culturally and geographically diverse sites in Europe to test out the recommendations and the knowledge transfer mechanism.

Projects should make use of the CCAM Knowledge Base[83] to support their findings, but also as a platform to share lessons learnt, results, and, if applicable, tools and datasets, thereby facilitating the transferability of the project's knowledge outputs.

Projects should involve Social Sciences and Humanities (SSH) expertise, and are encouraged to ground their work in participatory processes to support their proposals/ findings.

International collaboration is encouraged for benchmarking and exchanges of how cultural and regional diversity aspects are handled in CCAM deployment and development.

D6-1-9. CCAM effects on jobs and education, plans for skills that match the CCAM development, and prerequisites for employment growth (2023, RIA)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	

Expected outcomes:

Project results are expected to contribute to all of the following outcomes:

- Improved understanding of the short, medium and long term employment effects (e.g. working conditions, shifts in responsibilities, future roles and driver's skills depreciation) and wider socio-economic effects (income segregation, geographic dispersion, availability of entry level jobs) resulting from CCAM deployment.

[83] https://www.connectedautomateddriving.eu/

- Insight on demands for new or updated skills for the range of professions involved in the provision of services for persons and goods movement through CCAM. This goes beyond jobs directly involved with vehicles, such as driving and operating (e.g. ensuring services at end-points).

- Plans for CCAM skills development and enhancement, as well as for boosting awareness and promoting a conscious use of CCAM services throughout different education stages (from primary to higher education).

- Prerequisites for job creation, job growth, and for how to boost capabilities to innovate and develop competitive CCAM solutions and associated businesses.

- A roadmap for realizing new opportunities and future needs in relation to the wide range of professions associated with CCAM services.

Scope

In order to make the socio-economic transition to CCAM just and fair for all, enhanced awareness and proactive planning are required to anticipate and mitigate potential job losses and job relocations, and to ensure that necessary skills are available across a wide range of fields (from mobility operators, IT staff, drivers and non-drivers, to administration and management in transport).. While concerns and future needs regarding the impact of automation on the transport sector have been identified and investigated[84,85], CCAM solutions still provide high expectations on CCAM for job creation and job growth, which will only appear with the mass deployment of CAD in transport services[86].

Several H2020 projects have looked into the socio-economic impacts of automation across different transport modes (air, rail, road, waterborne) in order to provide policy recommendations that keep pace of this rapidly developing mobility transition. WETANSFORM[87] is creating a platform and "Living hub" to host discussions between relevant stakeholders on the effects of automation on transport labour. SKILLFUL[88] has defined specifications and components of curricula and training courses, including up- and reskilling of professions involved in the transport chain (e.g. drivers, infrastructure operators), as well as new business roles in the education and training chains. But in order to have a better and broader understanding of the short, medium and long term impacts of CCAM on jobs, employment, skills and knowledge, more targeted studies are needed, i.e. dedicated to

[84] ECORYS: Study on exploring the possible employment implications of connected and automated driving. Final Report. Rotterdam, October 2020.

[85] European Commission: Study on the social dimension of the transition to automation and digitalisation in transport focusing on the labour force. Final report. Brussels, 2021.

[86] ECORYS: Study on exploring the possible employment implications of connected and automated driving. Final Report. Rotterdam, October 2020.

[87] https://wetransform-project.eu/

[88] https://skillfulproject.eu/

the road mode, going beyond the driver or potential driver and taking into account specific penetration scenarios.

Indeed, according to a 2020 ECORYS study exploring the possible employment implications of connected and automated driving, the transition to CCAM is expected to relocate a number of jobs in the automotive industry as well as in transport services, thereby creating a spatial mismatch in labour demand and supply of which the rebound effects are not properly understood. Importantly, the study suggests that some 10+ years remain to prepare for this mobility transition and large scale deployment of CCAM.

Building upon the results from the above-mentioned projects, efforts should be directed at anticipating and mitigating potential job losses across a wide range of professions and fields, as well as towards boosting innovation capabilities while ensuring the availability and upscaling of specific skills. In addition, a key challenge will be to continue to raise awareness within the stakeholder community to better understand and anticipate upcoming socio-economic needs and requirements through proactive planning.

In order to successfully address the expected outcomes projects must:

- Develop a roadmap (including educational planning, prerequisites for job growth and strengthened innovation capabilities) for realizing new opportunities with CCAM, and meeting short and long-term demands for skills due to CCAM deployment. Impact on jobs to respond to the spatial mismatch in labor demand that has been identified in existing studies should be addressed, and the wide range of professions that can be associated with CCAM services should be considered, highlighting any particularities between the transport of persons and of goods.

- Analyse socio-economic and employment effects of CCAM taking into account different types of operations including people transportation and freight. Include the full range of professions involved in service chains. Also include aspects induced by new emerging business models. Study the role of road transport as an entry point into work-life and how it may be affected by CCAM. This should consider different combinations of degrees of penetration of mobility solutions with automation levels (3-5).

- Identify short and long term demands for updated skills and enhanced knowledge for the range of professions involved in the complete chain of services involved in provision and use of CCAM mobility for persons and goods. This goes beyond jobs directly involved with vehicles, such as driving and operating, and may also include e.g. ensuring persons getting safely into a building at their destination and intermediary service providers. For logistics this will be the whole ecosystem involved from goods production to deliveries to the end recipient. When the ecosystem changes with automation new business models, companies and workforce needs emerge. Assess the size of the skills gaps.

- Design schemes for skills development and enhancement throughout educational chains by means of use cases, paying particular attention to potential mismatches in skills and spatial demand and supply. Consider at least three use cases for groups of people that are directly or indirectly involved in provision of CCAM services. A variety of angles should be covered, including young persons or school children, private and public sector, passenger mobility and freight. Also include activities for boosting awareness and promoting a conscious use of CCAM services. A multidisciplinary approach is encouraged.

- Define and assess how expectations for job growth enabled by CCAM development and deployment can be achieved. Identify mechanisms and options to enhance innovation capabilities to develop competitive solutions.

Projects should involve Social Sciences and Humanities (SSH) expertise. Involvement of labour market competencies is encouraged.

D6-1-10. Robust Knowledge and Know-How transfer for Key-Deployment Pathways and implementation of the EU-CEM (2024, CSA)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Coordination and Support Action
Technology Readiness Level	.

<u>Expected outcomes:</u>

Project results are expected to contribute to all of the following outcomes:

- Extended and up-to-date CCAM Knowledge Base[89] to further support the CCAM Partnership with an enhanced expert network, including CCAM projects, demonstration and deployment initiatives, to facilitate the exchange of best practices, including tools

[89] https://www.connectedautomateddriving.eu

and methodologies to support the transition to a large-scale deployment of CCAM by 2030.

- Well maintained network and forum of experts in the different thematic R&I fields of CCAM.
- Adequate tools and processes to enable the exchange of experiences and practices, stimulate collaboration and cooperation between all CCAM stakeholders and reach consensus on challenges and future R&I needs.
- EU CCAM common evaluation methodology widely used in Europe.

Scope:

A common basis for CCAM Knowledge in Europe is available today with the online Knowledge Base on CCAM, which constitutes a one-stop shop for all relevant R&I initiatives, tools, methodologies, regulations and standards in the field. In the next few years, the Knowledge Base shall be expanded and adapted to the needs of all relevant stakeholders and provide more targeted content to specific stakeholder categories. The proposed action will ensure the maintenance and expansion of the Knowledge base as well as the regular exchange of all stakeholders in the area of CCAM in the medium to long term[90].

The action will organise exchanges with the broader stakeholder community in Europe and at international level on relevant results from European and national projects as well as on general challenges, barriers and needs within the thematic R&I clusters of the European Partnership on CCAM. In particular, the work of the CCAM States Representatives Group and the cooperation between Member States/Associated Countries for increased sharing of knowledge and best practices shall be supported. The action will establish an operational exchange and learning mechanism between the different national stakeholders and approaches, especially with regards to transferability, collaboration & matchmaking and create a common perspective and understanding of national research and deployment initiatives. It shall provide support for stakeholders to move into operations, provide and enable capacity building for key actors of different use cases /applications domains as well as for citizens (non-experts).

The EU Common Evaluation Methodology (EU-CEM) developed in CL5-2021-D6-01-06 aims at becoming the basic methodology to be applied in all CCAM related evaluations. This action will support the practical implementation of the CEM (for existing and innovative use-cases but also in alignment with national mobility strategies and regulations) and provide training programmes for CCAM projects to integrate the methodology. As such, this action will continue to evaluate and update the CEM accordingly, through targeted discussions with Member States and by looking at both national and regional transport and mobility data to ensure compatibility.

[90] The action shall build upon the work carried out by the project resulting from the call CL5-2021-D6-01-06.

D6-1-11. Data exchange for CCAM tests and early operations to support and learn from large scale demonstrations (2024, RIA, TRL 5)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex B.

Expected outcomes

Project results are expected to contribute to all of the following outcomes:

- Establish a CCAM data space, including common infrastructure components (metadata broker, identity management), governance and recommendations (ontologies and data formats), to facilitate and support data exchange of research and test data;
- act as a test bed for the development of CCAM functions and services from the perspective of data exchange;
- support exchanging data for validation of CCAM functions;
- make more relevant, high-quality datasets available for research with a clear focus on the usage of this data by different stakeholders;
- connect to other data spaces to facilitate the development of new functions and services; and
- create connectors to other data sources, including National Access Points (NAP), mobility service providers or toll systems;
- ensures a fair playing field for data exchange within the CCAM ecosystem.

Scope

Europe is building a data economy by establishing domain specific data spaces based on data sovereignty and on common principles for data exchange and access, built on trust and transparency, and respecting data ownership and law to ensure a competitive market. A federated data ecosystem that is specific to CCAM will be necessary to incorporate automated vehicles, fleets, mobility services and traffic infrastructure in the transport system.

A test data exchange framework for CCAM has been developed by previous initiatives to improve cooperation across large-scale demonstrations, pilot projects and stakeholders and foster the reuse of CCAM test data. It includes a collection of best practices and guidelines, specifications for data labelling and common data formats as well as tools and documentation. These principles will be demonstrated in a project resulting from the call CL5-2021-D6-01-06, under the form of a common openly accessible prototype platform, an important building block towards the establishment of a more extensive and inclusive CCAM Data Space.

Proposed actions will build upon the above demonstrator and existing European federated data infrastructures to:

- Define the governance of the CCAM Data Space, thereby extending the test data exchange framework and including identity management, as well as maintaining a metadata catalogue, ontology and harmonized data formats.
- Extend the capabilities of the CCAM test data exchange framework to include all core infrastructure components to enable and facilitate data exchange between large-scale demonstrations, living labs and deployment initiatives.
- Make relevant and well-described existing high-quality datasets available, which will be provided and used by other actions and entities.
- Include additional connectors (NAP, mobility service providers, toll systems, according to use cases).
- Identify synergies between the different tools and datasets developed by existing and upcoming CCAM projects, in particular from Cluster 3 (Validation[91]), Cluster 4 (digital infrastructure) and Cluster 5 (Key Enabling Technologies) and build the necessary connectors to ensure compatibility.
- Assess economic benefits of cross-sectorial use cases and enable data exchange with other related data spaces to foster innovation (e.g. mobility, supply chain, energy) and support the development of the identified use cases.

Links should be established with the Mobility Data Space initiatives from Digital Europe, federated data infrastructure projects (Gaia-X, International Data Spaces, BDVA) as well as

[91] Project resulting from the topic “Generation of scenarios for development, training, virtual testing and validation of CCAM systems”

with the CCAM Partnership's Cluster 1, Cluster 3 and Cluster 4 R&I areas respectively to incorporate results from large scale demonstrations (Use Cases, scenarios and Digital Twins).

Multimodal transport, infrastructure and logistics

D6-2-1. HORIZON-CL5-2024-D6-02-XX: Optimising multimodal network and traffic management, harnessing data from infrastructures, mobility of passengers and freight transport

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex B.

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

- Optimised multimodal transport network and traffic management, for efficient door-to-door mobility of passengers and freight.
- Effective and secure data exchange across all modes of transport, for dynamic and responsive multimodal network and traffic management.
- Validated systems for accurate detection and resolution of network bottlenecks, improving safety, security, resilience and overall performance of the transport network.
- New tools and services for optimising mobility of passengers and freight, in cities and other areas, cutting traffic jams and improving multimodal traffic flows.
- A reduction of 30% in transport emissions of greenhouse gases and other pollutants by 2030, in comparison to 2019 levels (pre-COVID-19 pandemic).

- Workable governance arrangements for multimodal transport network and traffic management, in view of further regulatory and policy actions.

Scope: Optimised multimodal network and traffic management is essential for an efficient transport network and seamless door-to-door mobility of passengers and freight. Such advanced capabilities can be supported by harnessing data from physical and digital infrastructures, as well as from the mobility of passengers and freight, involving different types of vehicles and vessels (including zero-emission, connected and automated), technologies and the use of innovative services. At the same time, novel forms of mobility (e.g. shared and micro-mobility) and new services (e.g. Mobility as a Service) present new challenges, but also great opportunities for enhanced management and optimisation of the transport network. This includes advances to fully utilise dynamic and interoperable data exchange from multiple actors and transport modes, for well-tested and validated systems and operations, with appropriate governance arrangements in place.

In this context, building on best practices (technological, non-technological and socio-economic), ongoing projects on multimodal network and traffic management, as well as other initiatives (e.g. the Digital Transport and Logistics Forum and the common European mobility data space), actions should address all of the following aspects:

- Developing and testing new generation multimodal, flexible, agile and adaptable, secure and resilient transport network and traffic management systems, leveraging state of the art technologies (e.g. artificial intelligence, big data, edge computing, internet of things).

- Assessing and simulating the effects on multimodal network and traffic management of new forms of mobility (e.g. zero-emission, connected and automated vehicles, car sharing/pooling, active-, micro-mobility, sustainable transport modes and drones), as well as of innovative services (e.g. Mobility/Logistics as a Service), in different urban and rural environments, while considering citizens' and corporate user needs (including vulnerable and different gender groups).

- Performing simulations for network-wide optimisation of emission traffic models, solving towards a "social optimum" and an effective assessment of mobility options for multimodal travel (leveraging public transport) and freight flows (including the last-mile), while addressing planned and unplanned events requiring early detection and (self-) resolution of mobility and freight systems under disruption.

- Demonstrating the collection, integration, analysis and use of network-wide data from infrastructures, vehicles/vessels and users (using ICT and EU satellite-based systems), from across transport modes, stakeholders and national borders, while preserving data privacy, enabling effective and intelligent multimodal network and traffic management, and even further data exchanges with other sectors (e.g. energy and telecoms).

- Performing early pilot activities on multimodal network and traffic management of limited scale in mobility hubs (e.g. rail nodes, maritime or inland ports), where cross-modal or hinterland inter-connections are present for passenger and freight traffic flows.

- Designing and testing innovative multimodal network and traffic management services, offered by public and/or private stakeholders, which can be operated at network centres (e.g. at cities or hubs) and/or at decentralised level (e.g. by users or vehicles/vessels themselves).

- Developing and showcasing effective governance and dynamic incentive models, for the effective engagement of public and private stakeholders in interoperable data exchange, in the optimisation of transport network and traffic management and in promoting a better use of (public) transport systems.

- Evaluating the qualitative and quantitative impact of the proposed measures and project results, including on reducing transport emissions and energy consumption, with a clear baseline for each use case.

If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must describe if and how the use of Copernicus and/or Galileo/EGNOS are incorporated in the proposed solutions. In addition, proposals should describe the technological and societal readiness of the systems and/or techniques proposed for development and use, particularly in the case of systems based on Artificial Intelligence.

The multimodal aspects listed above are complementary and in synergy with actions foreseen in other parts of the Work Programme, such as in the areas of Connected, Cooperative and Automated Mobility, Rail traffic management (as part of EU-Rail Joint Undertaking) and Air traffic management (as part of SESAR 3 Joint Undertaking).

In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

D6-2-2. Technological and social innovation towards greener e-commerce and freight delivery choices by retailers, consumers and local authorities

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Year of call	2023

Expected Outcomes: Projects are expected to contribute to all of the following outcomes:

- Customers' needs and motivations to choose more sustainable delivery options are better understood. Retailers' and logistics operators support this process by providing information on the implications of delivery solutions.
- Consumers are aware and committed in using delivery strategies to reduce emissions and traffic congestion.
- Information on environmental impact of deliveries is provided transparently and in an understandable way by the retailers (in collaboration with logistics operators) to consumers.
- A wider range of sustainable delivery options and related incentive schemes (at least comparable to the existing ones e.g. in terms of price and convenience) are co-designed with customers and proposed by retailers, incentivised by customers' growing demand for greener choices and cities' regulations.
- Thanks to co-design and co-implementation of the delivery options, retailers and customers accelerate the adoption of ultralow or even zero-emissions delivery processes.

Scope:

To support changing retailers and customers' behaviours towards greener freight delivery choices, the research actions will have to develop co-created actions able to increase transparency and consumers' awareness of greenhouse gas emissions and other impacts of e-commerce and parcel delivery. They will have also to propose alternative greener delivery solutions and related incentive schemes to encourage customers to make sustainable choices, still in accordance with their preferences and in combination with competitive and sustainable retail value propositions. They will have to take into account and build on existing methods and standards to compare the emission in the transport value chain of B2C e-commerce, and to be developed in line with the Commission's initiative on EU framework for harmonised measurement of transport and logistics emissions – 'CountEmissions EU'[92].

Proposals will have to:

- Involving actively consumers (e.g. through consumer organisations) and retailers, develop guidelines and best practice for retailers to communicate transparently and in an understandable way the greenhouse gas emission footprint of deliveries.
- Taking stock of existing studies, assess which conditions would make greener delivery options attractive to consumers and which motivations and options would incentivise consumers to change their behaviour towards greener choices. Integrate an

[92] Commission's CountEmissions EU initiative (https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13217-Count-your-transport-emissions-%E2%80%98Coun tEmissions-EU%E2%80%99_en –

intersectional analysis of consumers' gender, age, and socioeconomic status to account better for the customers' variety of expectations and motivations and develop solutions which cater for all social groups.

- Co-designing with and engaging consumers and retailers, and taking into account the assessed motivations and incentives, develop a set of greener delivery options, which are at least comparable with existing delivery offering and account for the different consumer groups' needs and motivations to change their behaviour. Identify which options would be more suitable to the customers' group or groups more motivated to change their behaviours and act as frontrunners, thus leading to a more rapid adoption.

- Define the process and requirements for the retailers both to communicate transparently and in an understandable way the delivery options to the consumers and to adopt the greener logistics processes in practice.

- Develop and analyse different scenarios that implement measures towards both more transparent communication and implementation of cleaner and zero-emission e-commerce last mile deliveries to assess reduction of greenhouse gas emissions and air pollution.

- Test with selected retailers and representative customers, and in collaboration with relevant city authorities, the proposed guidelines to visualise the advanced information on emissions and the greener delivery options towards consumers. Assess their attractiveness to consumers, the potential impact on consumers' behaviours (including e.g. same-day delivery and returns) and their possible buy-in into more sustainable offering. In an iterative process develop and implement recommendations for improvement.

- Propose recommendations and solutions to support and incentivise the uptake of greener choices by consumers and retailers.

- Define indicators to measure and evaluate the successful communication and the implementation by the retailers as well as the adoption by the consumers of greener delivery options.

- Develop recommendations with and for city authorities to support the adoption of greener delivery options and choices.

- Strengthen the coordination and collaboration between e-commerce companies, industrial logistics stakeholders and cities, companies, research and civil society, in Europe and internationally, to give input to the project as well as disseminate and exploit results.

- Cooperation with the network of cities CIVITAS[93] should be planned as appropriate.

D6-2-3. Operational automation to support intermodal transport

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA
Year of call	2023

Expected Outcomes: Projects are expected to contribute to all of the following outcomes:

- Operational automation requirements for seamless intermodal automatic cargo transportation are defined.
- Benefits, in terms of reduced social and environmental impacts (GHG, congestion, working conditions) and reduced logistics and transport costs, as well as technological gaps of hubs' automation are assessed.
- Synergies among rail, road and waterborne research actions on automation relevant for freight transport are established (links to CCAM and Waterborne Partnerships, and EU Rail JU Flagship Areas 1, 2 and 5[94]).

Scope:

Automated vehicles and vessels, as well as related processes, are developed independently within the various transport modes and sectors. This creates gaps and disconnections in the actual use within the logistics operations, missing concrete new operational models and opportunities for end to end logistics that may support adoption and contributing to system integration and decarbonisation.

[93] https://civitas.eu/

[94] See draft EU-Rail Multi Annual Work programme at https://shift2rail.org/wp-content/uploads/2021/12/20211222_mawp_v1_agreed-in-principle_clean.pdf

Automation will change the way goods flow across all modes (possibly encouraging modal shifts to coastal shipping modes/smaller vessel fleets, railway transport modes, or alternative road transport usages) and is not well explored in terms of opportunities for the logistics supply chains and enabling increased usage of vehicles and infrastructures. A high level of operational automation can be reached in terminals and hubs (e.g. node-to-node operations undertaken in inland hubs, intermodal depots, logistics terminals, freight consolidation facilities), which offer controlled environments and repeatable processes but also in the operational domain of processes occurring in those places.

To ensure operational efficiency and support intermodal transport, proposals should:

- Identify gaps in automated transport technologies and logistics operations between modes and hubs.
- Assess benefits of autonomous vehicles and barges to intermodal and logistics and the role/benefits of seamless intermodal automatic cargo transport across transport modes (rail, road, waterborne).
- Investigate the requirements and define concrete benefits of seamless and automated logistics operations, particularly in intermodal terminals and hubs, linking rail, road and inland waterways with a focus on intra-European freight flows.
- With the support of machine learning, digital twins, robotic process automation and AI, and using historical operational data, compare and demonstrate benefits of operational automation to current standard flows and operations. Synergies for rail will need to be sought with the EU-RAIL Programme projects implementing the Flagship Areas 1, 2 and Destination 5[95].

If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must describe if and how the use of Copernicus and/or Galileo/EGNOS are incorporated in the proposed solutions. In addition, if the activities proposed involve the use and/or development of AI-based systems and/or techniques, the technical and social robustness of the proposed systems must be described in the proposal.

D6-2-4. Scaling up logistics innovations supporting freight transport decarbonisation in an affordable way

Specific conditions	
Expected EU contribution per	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless,

[95] See draft EU-Rail Multi Annual Work programme at https://shift2rail.org/wp-content/uploads/2021/12/20211222_mawp_v1_agreed-in-principle_clean.pdf

project	this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	IA
Year of call	2024
TRL	Reach at least TRL 7 (system prototype demonstration in operational environment)

Expected Outcomes: Projects are expected to contribute to all of the following outcomes:

- Reduced emissions by 55% *(to be checked)* by 2030 in the project networks, without reducing the overall performance of the logistics supply chain and taking account of all costs and externalities.
- Gains in terms of operational efficiency and environmental impact from the implementation of the Physical Internet [96] are clearly identified, demonstrated and measured.
- Logistics concepts speeding up freight decarbonisation and adoption of zero emissions vehicles/vessels and intermodality are developed.

Scope:

Building on previously funded projects and ongoing activities (e.g. Connecting Europe Facility, Horizon 2020 and Horizon Europe projects), ensuring compliance with the data sharing framework pursued by the Digital Transport and Logistics Forum (DTLF), and taking into account the development of the common European mobility data space, proposals will pilot, demonstrate and scale up collaborative solutions regarding logistics nodes, intermodal logistics networks connectivity, business and governance models. The focus will be on both digital and physical interoperability as well as on the adoption of zero-emission vehicles/vessels.

The proposals will have to research and demonstrate all of the following points:

- Demonstrate at least 20 working open standard processes, procedures and services across 10+ logistics nodes providing seamless access to users. Processes, procedures, and services must have an open access definition and scalability aspects need to be addressed.

[96] In logistics, the Physical Internet is an open global logistics system founded on physical, digital, and operational interconnectivity, through encapsulation, interfaces and protocols. *Montreuil, Benoit (28 November 2012). "Physical Internet Manifesto, version 1.11.1"*

- Develop and demonstrate further compatibility and interoperability of the full range of standardised intermodal transport units (from containers to boxes), also across transport modes.

- To achieve scalable intermodal logistics networks connectivity, demonstrate models and processes, supported by Artificial Intelligence, Internet of Things, etc., which can increase utilisation of assets and resources in actual logistics service providers' networks dynamically. These models should also consider how to increase the adoption of automated and zero-emission vehicles and the use of rail and inland waterways through intermodal solutions.

- Demonstrate tools, technologies and processes to achieve different types of flows compatibility (e.g. through shared standard boxes) and synchro-modal solutions over the logistics service providers' networks, involving shippers and retailers to that purpose.

- Demonstrate the benefit (e.g. GHG reductions vs increased operational costs) of decentralised inventory positions in the pooled logistics network allowing low speed intermodal transport for (re-)positioning stock levels and answering short term lead times with closer to consumer inventory positions (e.g. full visibility of inventory positions in retail networks extended to suppliers and logistics service providers).

- Test and demonstrate sound business and governance models and rules for resource-sharing across logistics networks, to ensure operational efficiency of freight movements irrespective of mode, nodal operations and freight characteristics.

- Test and demonstrate the functionalities and relevance of the data sharing framework, serving for optimisation of the logistic system, including through the establishment of an appropriate semantic model and its components, such as for instance distributed autonomous digital twins (or distributed multi-agent systems). Synergies for rail will need to be sought with the EU-RAIL Programme projects implementing the Transversal Topic on Digital enablers and Flagship Area 5[97].

- Develop and demonstrate scalability of the proposed solutions providing open access mechanisms and low thresholds to the system of logistics networks. Consider realising visualisation and simulation models and tools to show the practical use of collaborative models for the various types of stakeholders and the potential benefits based on actual cases. Develop specific actions to encourage, facilitate and ensure the access of SMEs and smaller players.

[97] See draft EU-Rail Multi Annual Work programme at https://shift2rail.org/wp-content/uploads/2021/12/20211222_mawp_v1_agreed-in-principle_clean.pdf

- Measure and demonstrate the benefits in terms of use of resources, throughput capacity and environmental impact of the scaled up horizontal collaboration among logistics networks (system of logistics networks).

If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must describe if and how the use of Copernicus and/or Galileo/EGNOS are incorporated in the proposed solutions. In addition, if the activities proposed involve the use and/or development of AI-based systems and/or techniques, the technical and social robustness of the proposed systems must be described in the proposal.

D6-2-5. Future proof GHG and environmental emissions factors for accounting emissions from transport and logistics operations

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	CSA
Year of call	2023

Expected Outcomes:

- Establish a comprehensive set of harmonised GHG emission factors for the transport sector;
- Explore synergies and establish horizontal cooperation among various organisational structures developing GHG emission factors for transport and logistics.

Scope:

Proposals shall develop a comprehensive set of harmonised emission factors for the transport sector (freight and passenger), covering GHG emissions (CO2 equivalent) of transport operations. The proposals should address values for the entire transport/logistics chain and take up the full energy lifecycle (Well-To-Wheel/Wake).

Emission factors that relate the amount of GHG emission to the unit of energy consumed (for an energy-based calculation), or to the amount of GHG activity (for an activity-based calculation) are the basis of any GHG calculation. The increased efforts for measuring effects of climate change in various segments of the transport sector resulted in a range of values developed within the organizational structures of different transport modes, research entities and countries. Some of this work led to legitimate testing and development of the methodologies for the calculation and use of emission factors, or the generation of values that represent fuel specifications for given applications. However, much of it has merely resulted in a proliferation of apparently similar values creating confusion in the marketplace and bearing the risk of selection of sources/values purely on the basis of what is beneficial to the individual entity rather than what is correct.

This problem becomes more important in conjunction with the development of a wide set of technical solutions combating climate change, particularly the new and increasingly complex zero and low carbon energy mixes, including e- and bio-fuels. These solutions are deployed in the market very often with the support of dedicated financial mechanisms and programs, based on the estimated GHG emission reduction associated with the specific fuel technologies. Not only is it important for the climate impact that the emission calculations are 'correct'[98], but when dealing with large amounts of transport energy even a small difference over an emission factor value can lead to a significant difference in the associated financial transaction. Without an agreed and validated set of default emission factors for a wide range of the most common energy sources and a mechanism whereby legitimate variations or new energy carriers can be regularly updated, many actions based on calculating GHG emission reduction can be considered to be a risk of conflict and associated legal dispute.

The proposals will have to address all of the following points:

- Review the existing emission factors derived from the key global sources, duly reflecting the scientific state of the art and ensuring the coverage of new and conventional fuels;
- Perform the gap analysis and develop emission factors for categories not yet covered, taking into due consideration new production pathways, and addressing the uncertainty and variation in the well to tank factors to be applied to the new fuels;
- Establish a clearer set of rules regarding:
  - Methodology – to ensure that the basis and legitimate use of the two fundamental methodology types (consequential and attributional) are properly understood and applied appropriately;
  - Boundaries of calculation – to ensure that boundaries are not accidentally or deliberately set in order to favour particular outcomes;
  - Common sets of fuel / energy specifications – to ensure that data labels and associated values are truly aligned between sources;

[98] There may be no such thing as a 100% correct value, but it is essential there is a consensus and linked convention based around values within an agreed, small uncertainty threshold.

- Assumptions about input parameters that can result in variations in output values based on local circumstances for specific production;
- The basis for new energy carriers to be calculated quickly and consistently in order to avoid delaying the deployment of new, beneficial solutions;

- Establish a simple guidance to the transport sector as to which emission factors are the agreed defaults, and why; under what circumstances an alternative can legitimately be used.

The proposal shall build on the existing and emerging EU regulatory frameworks (including Commission's proposal for the Fit-for-55 package and the new initiative on harmonised measurement of transport and logistics emissions – 'CountEmissions EU'), GHG emissions accounting standardisation activities (such as the future ISO standard 14083) and other relevant initiatives and projects. Given that emission factors are applied in a global transport market, efforts need to be made to ensure that internationally relevant bodies such as IMO or ICAO are involved alongside prominent European stakeholders.

D6-2-6. Climate resilient maritime ports - Innovative solutions to ensure sea port infrastructure resilience, safe port access and port operations as a means to mitigate disruptions caused by a changing climate

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).
Type of Action	IA
Year of call	2023

Expected Outcomes: Projects are expected to contribute to all of the following outcomes:

- Ensure resilience of infrastructure of a) sea ports, b) adjacent inland waterways servicing terminals c) connected hinterland land infrastructure, to extreme weather events by assuring at least 80% operability during the disruptions.
- Contribute with at least a 20% increase in modal shift to the sustainability of transport systems.
- Ensure resilience and smooth functioning of passenger mobility as well as freight transport and logistics networks operating on these infrastructures.
- Increase the use of recycled materials within or across transport modes by at least 30%.
- Reduce environmental impact (emissions, soil/water pollution, degradation of ecosystems and fragmentation of habitats) during construction, maintenance, operation and decommissioning of the infrastructure in line with the EU environmental legislation.

Scope:

Research is needed in order to limit transport infrastructure vulnerability to climate change and other natural or human caused disruptions. Making infrastructures more resilient to climate change should focus on improving the ability of the transport infrastructure network to withstand disruption, adapt to changing conditions under extreme circumstances while maintaining its performance. The goal is to strengthen infrastructure reliability, improve its performance and increase the resilience of the whole transport system, creating a climate resilient infrastructure system.

Sea ports and waterways around the world are experiencing air and water temperature increases, rising sea levels, changes in seasonal precipitation and wind and wave conditions. Many are also seeing more frequent and severe extreme events such as storms, heatwaves and droughts. Climate change represents a significant risk to business, operations, safety and infrastructure – and hence to local, national and EU economies (although climate change may also have positive effects by reducing transport disruptions at certain locations, e.g. through the reduction of ice formation).

Extreme weather events affect transport infrastructures and their management. Even if infrastructures are designed to cope with various stresses along their life, the increase of frequency and severity of extreme weather events will, increase their deterioration pace and increase possibility of accidents that may become more frequent due to adverse weather conditions. Sea ports are particularly exposed to extreme weather events and are very important for the local and global economy, since nearly 80% of world freight is transported by ship. Seaports of Europe are gateways to other continents. 74% of extra-EU goods are shipped through ports. They are also important for intra-European trade: 37% of the intra-EU freight traffic and 385 million passengers pass by ports every year. A 50% growth of cargo handled in EU ports is predicted by 2030[99]

Port and waterway operators need to take urgent action to strengthen resilience and adapt. As costal structures, seaports are exposed to storm surges and sea level rise and are vulnerable to flooding. Climate change is expected to have more severe impacts in northern Europe, where Europe's top 20 cargo seaports are located. In total, 852 ports face the risk of inundation in 2080 and the number of seaports to be exposed to inundation levels higher than 1m is projected to increase by 80% from 2030 to 2080. The number of ports that face the risk of inundation is expected to increase by more than 50% from 2030 to 2080. This trend is even stronger on the North Sea coast, where according to the GISCO database over 500 ports are located with traffic accounting for up to 15% of the world's cargo transport (EUCC-D, 2013). In total, 852 important ports face the risk of inundation by the end of the century is 852[100].

At the same time when focusing at a resilient and performing transport infrastructure, its environmental footprint, resource and material consumption and habitat fragmentation and biodiversity degradation should be reduced to a minimum. The goal is smart, green, sustainable, climate-resilient and biodiversity friendly infrastructure.

The proposals will develop and validate new solutions to increase resilience, efficiency, inter-modality and safety of the transport system, for passengers and freight.

Proposals will have to:

- Develop solutions for ensuring the performance and safety of a) seaports, b) adjacent inland waterways servicing terminals c) connected hinterland land infrastructure, during periods of extreme weather events.

- Develop strategies minimising capacity loss of resilient infrastructures during disruptive events, securing infrastructure assets or delivering the necessary redundancy or adaptive capacity when at the same time avoiding over-designing, adopting an inappropriate or irreversible design, based on vulnerability analysis and risk assessment.

- Select some short-term or interim options that strengthen resilience or otherwise help to reduce climate related risks, can help to address uncertainties and avoid maladaptation by providing time to collect data, in order to prolong the functionality of an existing asset and avoiding locking in to a single climate change scenario.

- Demonstrate solutions to interconnect infrastructure health monitoring, traffic management and emergency management systems to support informed decision making during and after these events, also supporting possible redistribution of freight and passengers flows to complementary infrastructures.

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[99] https://ec.europa.eu/commission/presscorner/detail/en/MEMO_13_448

[100] https://publications.jrc.ec.europa.eu/repository/bitstream/JRC108865/jrc108865_final.pdf

- Build on innovative solutions for surveillance and prediction of climate change effects, such as the Destination Earth digital twins[101], and for identification of infrastructure points particularly vulnerable to climate change. Proposals should develop cross-modal strategies to upgrade (including physical upgrade) existing infrastructures and reduce their vulnerability, while using sustainable materials and construction techniques.

- Design of standard, modular infrastructure elements for rapid deployment after disruptive events in order to increase the capacity of the transport network or create new provisional links as a temporary measure until the transport network recovers its normal capacity. Both mode-specific and multi-modal solutions can be considered.

- Develop new governance models that enable cooperation across institutional, modal and national boundaries. Besides physical measures, consider, together with stakeholders and end users, deployment of social measures at various levels, development and demonstration of innovative concepts and solutions to make operations for freight transport, logistics supply chains and passenger mobility more resilient to large-scale shocks and disruptions by enhanced planning, management and flow redistribution (considering also shifting to less carbon-intensive transport modes).

- Develop standard models and procedures to foster the implementation of resilient methodologies from design and construction and throughout the life-cycle of the infrastructure allowing in the best way to address climate risks and hazards. Present a 'portfolio' of potential measures (structural, operational and institutional), and provide guidance on how to screen and evaluate options.

Innovative infrastructure solutions should contribute to lowering the environmental footprint, resources and material consumption. Exploring Nature-based solutions (NBS) is an opportunity for creating sustainable, climate-resilient EU transport infrastructure in a cost-effective manner, while producing substantial social, economic, and environmental co-benefits. The goal is smart, green, sustainable and climate-resilient infrastructure, planned in a way that maximises positive impact on economic growth and minimises the negative impact on the environment and, significant and lasting degradation of ecosystems and fragmentation of habitats, promoting environmentally friendly modes of transport and leading to the reduction of transport emissions.

Proposals need to include at least three pilot demonstrations in operational environment (minimum at TRL7) in CEF corridors for 3 sea ports with inland waterways terminals by selecting the most effective measures and combinations of measures and determining how and when they can best be implemented over time as conditions change. Proposals should also consider results from previous calls on infrastructure resilience and sustainable construction

[101] https://digital-strategy.ec.europa.eu/en/activities/work-programmes-digital, main work programme, section 5.1.1

and should uptake relevant EU guidance on development and management of EU transport infrastructures and be compatible with EU environmental legislation.

D6-2-7. Improved transport infrastructure performance – Innovative digital tools and solutions to monitor and improve the management and operation of transport infrastructure to increase the reliability, safety and sustainability of the network

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Eligibility conditions	The conditions are described in General Annex B. The following exceptions apply: If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).
Type of Action	IA
Year of call	2024

Expected Outcomes:

- Better interconnection of transport infrastructure, transport means, users and goods, optimised door-to-door mobility, increased safety and security, less environmental impact and lower operations costs. Seamless, integrated and self-explanatory use of different transport modes and easily integrated innovative technologies.
- Enhanced and safe coexistence of various forms mobility (e.g. soft, active mobility, shared mobility).
- Increased by 30% performance, robustness and efficiency of infrastructure for all modes of transport. More inclusive, comfortable, accessible, personalised and flexible infrastructures and multi-modal services.
- Lowered by 30% transport emissions.

- Lowered by 30% number of accidents.
- Enhance prediction of demand from individual behaviours, enabling appropriate modal capacity and demand management.

Scope:

Innovative digital tools and solutions will allow to upgrade transport infrastructure ensuring an adequate performance, safety, reduction of emissions and inclusiveness. Increasing the performance of multi-modal transport infrastructure can be achieved through improving the productivity of the assets and cross modal data management. Digital solutions are key to reduce drastically traffic disruptions of transport flows.

Transport infrastructure needs the ability to harvest the benefits from digitalisation at management and operations levels as well as in the relation with the user. Digitalisation can support the achievement of sustainability targets and provide a better service to infrastructure end users, including enhanced public transport services. Digital technologies, such as big data, the Internet of Things and Artificial Intelligence techniques provide a great potential for developing mobility solutions.

The integration between transport infrastructure and digital technologies will provide personalised seamless journeys and freight across different transport modes. This integration will consider safety and security as from the design phase, while simultaneously automating and accelerating the decision process at every level from maintenance to traffic management.

Special attention is to be paid for persons with disabilities and older persons to the accessibility of new digital tools in order to ensure that this segment of the population are also able participate fully in benefits of digital progress.

The proposals will have to:

- Improve performance of transport infrastructure and multimodality with the use of IoT, edge computing and decentralised artificial intelligence, in view of its potential to facilitate real-time decision-making, improve safety and to save bandwidth and energy.
- Include solutions for self-monitoring, self-reporting, non-intrusive inspection and testing methods, including advanced predictive modelling.
- Demonstrate ability to process internal and external raw data, such as sensor data, into smart data that can be used to optimize infrastructure management processes.
- Building on the common European mobility data space, facilitate the seamless use and provision of data and information to the end user across the transport infrastructure network and logistic chain, with a view to progress advancing towards smart mobility concepts for passengers and freight.
- Demonstrate ability to limit emissions and other pollutants.

- Develop measures for the improvement of the safety for infrastructure workers and end users.

Proposals need to include XX pilot demonstrations of the proposed solutions in operational environment (minimum at TRL7) on land and inland waterways transport infrastructure. Proposals should consider results from previous calls on infrastructure digitalisation, and on edge-IoT, and focus on validation of innovative solutions (i.e. IoT, edge computing and AI).

D6-2-8. 2023: Shaping the future transport and mobility systems

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions

Expected Outcome: Projects are expected to contribute to several of the following outcomes:

- A better understanding of the effects of governance[102], policies[103], and incentives on the choice of individuals, families or social groups of different kinds to use a specific transport mode.
- Reinforced public engagement in shaping transport and mobility policies.
- Effective policy interventions, co-created with target constituencies and building on high-quality policy; strengthening of research-policy cooperation models to reinforce impact and trust in science; building bridges of communication between science, policymakers and society.
- More effective national and regional mobility policies toward sustainable and accepted approaches, based on a system-thinking perspective.

[102] Governance is all the processes of interactions be they through the laws, norms, power or language of an organized society over a social system, done by the government of a state.

[103] Policies are deliberate systems of guidelines to guide decisions and achieve rational outcomes. Policies are generally adopted by a governance body within a national or local authority.

- Better harnessing the potential of digitised mobility data while protecting citizen's privacy.

Scope: Governance, policies and incentives play an important role in shaping transport and mobility systems and influence the development and implementation of different technologies and modes of transport (e.g. walking, cycling, rail). It is therefore important to study how policies and regulations could be best used to govern transport and mobility systems in desired directions, so that they become more sustainable and just, for instance with regard to gender, place, or low-income households, as well as their fiscal impacts.

Proposals should analyse the influence of politicians on the making of – sustainable and non-sustainable – transport policies, as well as the impact of the design of transport and mobility policies on accessibility in geographically peripheral areas. The mobility, energy, economic and societal systems being all interconnected, proposals are expected to propose approaches that better integrate mobility policies with policies from other sectors (e.g. energy efficiency, renewables, gender mainstreaming, poverty reduction).

Actions should also explore how cities and metropolitan areas manage the emergence of micro-mobility and how driverless vehicles will affect urban areas and land use (e.g. land used for parking). Synergies with the reform of governance instruments of the European Union (e.g. Trans-European Transport Network) should be made in order to enhance the 'phase-out' policy effect for private car use and achieve the decarbonisation of mobility across Europe.

To ensure that mobility data are best utilised for the common good, regulations and accountability measures are needed, for example, harnessing the potential of data to stimulate innovation and guide urban planning, while also protecting citizen privacy. Such measures should be identified within the project activities. Furthermore, the drivers for public acceptability of stringent and mandatory transport policies (e.g. carbon taxes, urban traffic bans) should be analysed.

A 'social optimum' balance should be included to developing research knowledge within new governance models from several perspectives (e.g. socio-economic, environmental, health, accessibility, gender and inclusion, safety and security aspects). This concept complements the work launched within the Cities Mission regarding MaaR (Mobility as a Right).

Actions are expected to involve citizens from different backgrounds and origins in the policy analysis in order to gather and study their understanding, perceptions, opinions and positions, thus helping to elaborate the most appropriate policies' recommendations. The collection of children's views can also be included in the study. Citizen platforms if existing, can be used for this purpose.

This topic requires the effective contribution of SSH disciplines and the involvement of SSH experts, institutions as well as the inclusion of relevant SSH expertise, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

Safety and resilience

Safety in Urban Areas/ Road Transport Safety

D6-3-1. Effects of disruptive changes on transport safety issues (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcomes:

Research is expected to contribute to all the following outcomes:

- Transport systems prepared for disruptive changes, supporting continuously improved traffic safety.
- Resilience as an integrated principle in the design and development of future transport systems.
- Increased understanding of the underlying psychological effects and reactions to sudden changes in availability of transport means, as well as authority interventions, inflicting the safety of users.

Scope:

The importance of a robust transport systems becomes highly evident in times of rapid, unplanned changes. The COVID-19 pandemic has pointed at several issues that need to be addressed to secure future resilience in the transport systems and to ensure that the level of transport safety is not only maintained, but also meeting more demanding targets. For instance, the decreased use of public transport during the pandemic has to some extent led to increases in both biking and walking, but also an increased use of cars in some parts of the world. At the same time, decreased traveling has meant fewer vehicles on the roads in certain areas, whereas others have seen an increase of delivery vehicles, as home deliveries have surged.

Urban air mobility (UAM) is an ever-growing topic of discussions that goes beyond the boundaries of technological developments in the aviation industry, attracting the attention of mobility actors and local authorities as a means of contributing to sustainable and integrated mobility across cities and regions.

Digital tools/services and new transport means (e.g. urban air mobility and micro mobility), new ways how to use the infrastructure (e.g. shared space) and new behaviour should be included.

In order to provide safe and resilient transport for all, many aspects must be considered in a clearly multidisciplinary approach, such as:

- Safety implications of rapid changes / new incentives (sometimes contradictory to previous ones)
- Socio-economic differences: How do they affect the safety of individuals?
- Resilience at the system level: How can that be applied and used for improved transport safety?
- How can safety and resilience be improved by future housing developments/suburban planning?

A definition of a resilient transport system shall be provided and transport safety factors be determined that are essential to take into account. Moreover, scenarios for disruptive changes shall be identified that can make a transport system instable, the consequences on transport safety be analysed, and solutions to tackle them be developed. Hence, a structured method to secure safety as an integrated part in resilient transport systems shall be provided.

A solid foundation for this research is the Safe System Approach. It requires the inclusion of relevant expertise in social sciences and humanities (SSH) and will benefit from international cooperation.

D6-3-2. Establishing a framework to improve traffic safety culture in the EU (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcomes:

Research is expected to contribute to all the following outcomes:

- Growing a positive traffic safety culture across the EU that supports the Vision Zero goal and the Safe System Approach, and which is in line with the UN Sustainable Development Goals and the 2020 Stockholm Declaration, UN General Assembly Resolution and Global Plan of Action for the second decade on road safety.
- Remedial action against detrimental, non-temporary impacts of the COVID-19 pandemic on certain road safety risk factors such as a shift from collective to individual means of transport. Facilitation of a shift to increase efficiency in road safety related public spending across Europe.
- Development and evaluation of strategies to transform the traffic safety culture of road users and stakeholders based on a valid model that identifies the key components defining traffic safety culture, including social norms, attitudes, perceived control, values, and system assumptions.
- Concepts and guidelines to make the concept of traffic safety culture an integral part of road safety work of actors across the socio-economic systems of European societies.
- Better understanding of the link between road safety outcomes and safety culture; pilot implementation of road safety education at secondary school level and also for decision makers and practitioners in Member States.

Scope:

- A Safe System entails the understanding and managing of all elements of the transport system, including the behaviour and interplay of its actors. Comparative analysis shows persistent differences in road safety performances between EU Member States. These differences may be attributable to differences in culture, which are hard to explain with classical risk models. Efforts shall therefore be made to complement road safety initiatives by a *safety culture* perspective, i.e., the values, beliefs, priorities and viewpoints shared among groups of road users and stakeholders that influence their decisions to behave or act in ways that affect safety. This concept is already well established in organisational research. Assessing road safety cultures in different national, regional or local systems, groups and organisations is believed to help understanding and explaining different patterns of risk perception and risk taking across communities and countries – and can likewise inform tailored interventions for these (sub-)cultures, which all come with their specific norms, values, beliefs and behaviours. These interventions should address all relevant actors in the system for road transport of people and goods, and consider future developments, such as potential impacts by increasing automation levels or by the introduction of new means of road transport such as e-scooters and hover boards.

Within this context, actions should contribute to establishing a framework for cultural transformation in road safety across the EU and thereby address all the following aspects:

- Better understanding of the link between road safety outcomes and safety culture, i.e. of sociocultural factors like values, beliefs, attitudes, and norms and their effects on actual behaviour of road users (including subjective perception of safety as well as implications of value of time and institutionalised travel costs) – and the ways how these factors can be sustainably transformed.
- Consideration in particular - but not exclusively - of traffic behaviour with high safety impacts, such as inadequate speed choice, distraction by communication or control devices, driving under the influence of alcohol or drugs, non-use of protective devices, and risks triggered by professional drivers' requirements to multitask and report while driving.
- Assessment of safety cultures and respective activities from other transport modes such as aviation and rail and their potential for road safety.
- Consideration of safety impacts of new technologies (including better understanding and use of Advanced Driver Assistance Systems (ADAS)) and emerging transport means and services.
- Stocktaking of good practices from countries and companies worldwide already successfully applying cultural approaches to (road) safety work, including countries outside of the EU such as the US and Australia.
- Targeting all levels of the socio-economic systems of societies in the EU, i.e. from European to national, regional and local communities, including entities such as schools and workplaces. Also NGOs, victims' organisations etc. can play an important role in that regard.
- Clear guidance & hands-on advice on the design and evaluation of interventions to define, measure, transform and institutionalise traffic safety culture across all areas affecting road safety – for decision-makers and practitioners, with a good geographic coverage across EU institutions, Member States and Associated Countries. At the level of individual road users, such interventions may entail targeted educational and communication efforts to challenge wrong beliefs or to clarify misperceived social

norms, and the use of incentives and nudging to encourage compliant behaviour. At the level of enterprises and authorities, initiatives may include the take-up of safety culture principles in sustainability reporting and encompass various activities from staff training and supervision to procurement and operations – at best permeating work culture and norms of an organisation. Advice at the level of Member States and the EU is sought on how to support such transformation such as with legislation, enforcement, and data.

- Pilot testing of selected interventions at various levels in the Member States.

Actions should be based on the results of previous research projects in this domain, such as the TraSaCu project, and make advances by completing and updating their theoretical foundations, teaming up with EU stakeholders and bringing their findings to life by establishing a framework for true cultural transformation in road safety both among stakeholders and road users.

Special attention should be given to EU countries with lower safety performance.

Integration of relevant expertise from social sciences and humanities (SSH) and international cooperation with partners from the US and/or Australia is encouraged.

D6-3-3. Better infrastructure safety on urban and secondary rural roads throughout a combination of adaptable monitoring and maintenance solutions (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

<u>Expected outcomes:</u>

Research is expected to contribute to all the following outcomes:

- Enhanced criteria catalogue for road safety assessment with particular applicability for non-trunk.

- Roads and the safety impact on all – including new – types of users.

- Technology for the real-time generation and communication of infrastructure Key Performance.

- Indicators (KPIs) related to safety, including those created/derived from vehicle sensor data.

- Concepts for interaction of infrastructure elements in a digitalised ecosystem for road safety.

Scope:

Road infrastructure can be improved to decrease the risk of crashes and other incidents as well as crash severity. The benefits of this will be amplified in a connected transport system where automated or partially automated vehicles are supported by infrastructure features to perform as expected. In addition, road infrastructure can provide clear guidance towards desirable road user behaviour, which may lead to more predictable behaviour, and consequently to less crashes.

It is essential to understand how to upgrade the infrastructure network to make it compatible with all road users (e.g. powered two-wheelers are not considered as users for which urban infrastructures are usually designed) and in particular with automated vehicles at different levels of automation. The research should focus on urban and secondary rural networks as most of the resources for upgrading the road network is often devoted to primary networks (with specific attention to the Trans-European Road Network). For urban and secondary roads, resources are generally limited, and potential negative impact of roadworks on the surrounding territory is extremely relevant. Low-cost interventions with low negative impact need to be studied for these roads.

Advanced monitoring, warning and maintenance techniques need to be developed to guarantee a timely assessment of the operating conditions of road structures and furniture. Recent events have highlighted the importance of roadside safety devices monitoring, but also proper signs and marking, pavement and overall road structures (bridges, tunnels etc.).

The results of the research will enhance the safety level of the infrastructure by enabling a prompt reaction to potentially unsafe conditions and will enable to identify the infrastructures where connected, automated vehicles can travel under safe conditions.

Aspects to be addressed shall include:

- Identification of criteria to perform safety assessments of urban and secondary rural roads accounting also for new users (including but not limited to powered two-wheelers, e-bikes etc.) and to identify cost effective upgrade solutions.

- Further development of infrastructure measures to elicit desired road user behaviour.

- Development of new technology for monitoring and communicating in real time infrastructure distress conditions and deterioration. This should include malfunctioning and post impact warning for road equipment.

- Integration of safety and V2I issues in asset management to ensure that the infrastructure is always capable to provide the minimum required level of performance to provide safe travel conditions for automated vehicles (ISAD concept).

- Development of new maintenance techniques for road equipment with low negative impact on the surroundings (including but not limited to roadside safety features, signs and marking, lighting).

- Connection of infrastructure elements to the digitalised ecosystem, including but not limited to research on digital twins.

- Development of onsite data storage and communication systems (e.g. RFID) capable to provide in real time details on the properties of the road equipment relevant to road safety.

- Use of data from connected probe vehicles to detect safety relevant conditions and collect maintenance indicators.

- Pilot testing of selected interventions.

Actions should be based on the results of previous EU projects.

D6-3-4. New ways of reducing serious injuries and the long-term consequences of road crashes (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

<u>Expected outcomes:</u>

Research is expected to contribute to all the following outcomes:

- Validated mechanisms of personal injuries leading to significant long-term consequences, for all road users (pedestrians, bicyclists, motorcycle riders, car and bus drivers and occupants, etc.).
- Established system for classification of long-term injuries, including methods for follow-up of personal injuries for the required time after a crash.
- Validated tools and methods for the assessment of injuries leading to long-term consequences, such as upgraded virtual human body models.
- Preconditions to develop policy, regulatory, and standard requirements for the purpose of reducing serious injuries, in particular those with long-term consequences.
- A general upgrade in protection for all road users through safe and robust countermeasures and solutions.

Scope:

In addition to fatal and near-fatal injuries, personal injuries with long-term consequences continue to pose a threat to personal mobility. Particularly pedestrians, bicyclists, and motorcycle riders, as well as users of new mobility devices, have a high risk to sustain personal injuries with long-term outcomes, such as brain and neck injuries. In cars, despite new collision mitigation systems, low and medium severity collisions may still cause similar permanent neurological disorders to occupants. Long-term injuries to both the upper and lower extremities are further examples, occurring among all road user types. As of today, neither any standardized nor any accepted method exists for the evaluation of solutions to reduce long-term outcomes. In addition, there is a need to include more aspects of human variability like age, sex, weight, and stature, with particular focus on long-term disability.

Several research areas, also social sciences, are required for the sake of understanding and reducing the long-term consequences fully. Cognitive capabilities could for example be impaired by physical head trauma, and there is at the same time a need for more knowledge of psychiatric impairment related to posttraumatic stress or reduced quality of life. In other words, cognitive issues and depression must be fully recognized as potential long-term consequences of road crashes.

More research is needed to establish a relevant system for classification of long-term or permanent disability that can be used for the development and design of future protective solutions as well as policies and requirements. There is a strong need for refined knowledge of the relations between initial injury and long-term consequences of personal injury, which will demand new in-depth crash data for the reconstruction of collisions combined with long-term injury follow-up. New models for measuring long-term consequences will need a lot of real-world data to become validated. In-depth analysis of data from hospitalized patients will in this perspective also continue to be needed as well as efficient means to follow up on psychiatric impairment measurable. Hence, new efforts in accident research are required, as well as the most related social sciences (economics and psychology), further to research in biomechanics, vehicle crashworthiness, and other aspects of crash dynamics. New technologies open possibilities for gathering new types of data with higher levels of detail.

Virtual testing tools are crucial for new more efficient evaluation methods, and accordingly further development of human body models (HBM) is particularly important. The effectiveness of new systems must for instance be assessed in a wide range of crash load cases, which the current test dummies cannot support, and another possibility with the use of virtual HBM will be to evaluate integrated and adaptive safety at a significantly higher level of detail. The potential of HBM to be usable for the evaluation of long term injuries in product development is strong and will be supported by further multidisciplinary research. Research is also needed to assess any limitations in this respect.

Virtual methods with HBM should not only be developed further for passenger car safety, but for the purpose of assessing personal protection equipment, forgiving road infrastructure (including road surfaces), and the protection of motorcycle, moped and bicycle riders, as well as pedestrians and users of new micro-mobility devices against long-term injuries. Virtual HBM need to reflect human variability, and there is a particular need to focus attention on children in all different road user roles, e.g. preteens in passenger vehicles who normally are not seated in child seats, yet often too small to be fully protected by current vehicle integrated safety systems.

New and upgraded vehicle interiors (including non-conventional seating and new interior features) of highly automated passenger cars, shuttle buses (including mini buses), and other driverless passenger vehicles, will play an important role in the efforts to raise the road safety level further regarding passenger vehicles. Persons who are standing, for instance passengers in public transport, should also be included. Market drivers (e.g. increased automation, comfort, and infotainment) will be reinforced with safety-intended development strategies when supported by relevant research and policies regarding long-term consequences.

Research within this field is expected to recommend upgrades to concerned policies, regulatory requirements, and standards. For this reason, international cooperation is recommended.

Findings, knowledge, and experience are encouraged to be shared with other fields, such as certain sport, recreation, and work activities, as well as with other transport modes, which may have similar issues regarding personal injuries with long-term consequences as road traffic, although a different incidence.

Actions should take into account the results of previous EU research projects in that domain (e.g. Seniors, VIRTUA, SafetyCube).

D6-3-5. Human-technology interaction: ensuring the right level of driver vigilance with respect to the context and the automation level (2024)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	RIA

Expected outcomes:

Research is expected to contribute to all the following outcomes:

Until full automation in transport is reached, the driver will play an important role in vehicle safety. In this context, the proposed research will lead to human-technology interaction (HTI) systems for L0-L3 vehicles (with overlap to L4 vehicles) and development guidelines contributing to all the following outcomes:

- Increased road safety by ensuring that the driver has the right level of vigilance and situation awareness with respect to the context and the automation level and by facilitating the handling of high-cognitive load situations.
- Reduced number and severity of crashes related to low vigilance and/or misinterpretation during the hand-over and take-over phase.

Scope:

The increasing automation of road transport is bringing up new challenges especially in lower automation levels (L0-L3) when driving control is transitioning from the driver to the vehicle or vice versa. For these levels, ensuring the right level of driver vigilance with respect to the context and the automation level is important to avoid dangerous situations.

In addition, systems based on HTI are generally built on a non-stationary and non-deterministic foundation – human behaviour. Therefore, the concept of individually adaptive systems has to be followed and elaborated in all its particular aspects, as the consideration of “average” human behaviour is not sufficient.

This has large implications on the design of HTI systems.

To address the challenges, proposals should address all the following aspects:

- HTI systems should provide a reliable and seamless interface between the driver and the vehicle in normal driving conditions as well as in specific situations with a risk of generating high cognitive load, diverted attention, inattention, impaired driving or in the case of instantaneous limitations in driving capabilities.

- As drivers and their experience, as well as driving conditions may vary a lot, HTI systems will need to address a wide variety of use cases. Therefore, in-cabin monitoring systems with adequate accuracy are key to have a clear understanding of the driver state, while considering all contextual in/out cabin data, so that the vehicle can propose a pertinent and tailored strategy to prompt the required driver action or behaviour.

  Special attention should be dedicated to the "hand-over" and "take-over" phases. Hand-over/take-over requests should be done considering the context and the state of the driver in a way to minimize cognitive stress related to hand-over and take-over. In this context, it is important to investigate standardized requirements for the human-machine interface (incl. in case of system failure). Advances in cabin monitoring and sensing technologies as well as robust detection/prediction of driver cognitive status will be necessary to achieve these objectives.

- Research should address the development of:

  - Relevant strategies to avoid driver disengagement and reduce cognitive load in critical situations;

  - Behavioural models and methodologies to identify activities/behaviours that should be avoided or blocked by the vehicle HTI. These strategies should be scalable to the available vehicle sensing sophistication.

HTI systems should be upgradable both in software and in hardware with minimal disruption for the users, while ensuring that the intended effect and functionality is improved or at least maintained. A cross-fertilisation opportunity would be to investigate how other transport modes (e.g. aviation) handle upgrades/updates with minimal disruption for the user.

Social sciences and humanities (SSH) have relevance in the context of identifying driver acceptability criteria and pain points.

These research needs should be addressed in coherence with projects resulting from the call topics HORIZON-CL5-2021-D6-01-10 and HORIZON-CL5-2022-D6-01-02 (CCAM partnership).

Waterborne Safety and Resilience

D6-3-6. Ensuring the safety, resilience and security of waterborne digital systems (2023 or 2024)

Specific Conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Research and Innovation Actions
Technology Readiness Level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex B.

Expected Outcome: Project outputs and results are expected to contribute to the following expected outcomes:

- Increased safety and resilience of waterborne digital systems, including system of systems and their functions and considering both malicious intervention and system failure.
- Assurance of the resilience, safety and security of waterborne digital and connected systems is undertaken on the basis of robust methodologies to a similar standard to that applied within other sectors which apply safety critical digital technology and their application in safety critical conditions.
- Robust by design waterborne digital and connected systems for safety and resilience (incl. reliability regimes such as fail safe, fail secure, fail to operation etc., HAZOP, system of systems, security, hardware and equipment data, etc.)
- Methodologies to enable effective HAZOP analysis and validation of waterborne digital systems are developed and disseminated increasing the use of common approaches, also when using artificial intelligence applications.
- Increased software safety (incl. functional analysis and reliability assessment).
- Increased cyber security for operation and maintenance (incl. software maintenance).

Scope:

Increasingly, modern waterborne transport relies upon smart digital and connected systems to ensure safe and efficient operation. Within large complex vessels, system of systems approaches are used together with Internet of Things and Artificial Intelligence approaches to integrate diverse systems ranging from sensors, business and cargo management systems, power and engine management, electronic navigation and situational awareness. System integration of systems with proprietary digital control systems has become more and more critical in terms of ensuring safety and efficiency. The complexity and foundation upon software, makes assurance of the resilience of such systems challenging and requires a different to that applied to hardware based systems. Waterborne digital systems can be vulnerable to both malicious intervention and the consequences of system failure. Examples have included the spoofing of navigational GPS signals, ransom wear attacks on integrated container management systems, complete power shutdown and the helicopter evacuation of a large passenger ship when engine protection systems identified a common fault across all engine waterborne systems. The challenge to assure the safety and resilience of digital systems is particularly important within large complex vessels where the level of integration and connectivity is high and where the consequences of failure can be particularly severe.

In the domain of power generation and management the vastness of new technological solutions, often driven by environmental regulations, poses new challenges in ships' design and management, where the need for integration of diverse energy converters (ICEs, batteries, fuel cells, wind, capacitors, etc.) confront designers and operators with systems based on profoundly different operating principles coming together with different requirements and control and digital systems. Integration for harnessing the full potential in a safe and secure frame is key to their implementation.

Furthermore, the capability of integrating different systems (and their dynamics) involve an always increased number of sensors, whose data, fused, should become available for optimization, increased awareness during normal and safe critical operations.

Comprehensive HAZOP (Hazard Operability) studies are essential for such vessels, yet the methodologies are poorly established within the waterborne sector whilst other sectors operating safety critical digital systems (aerospace, nuclear, medical automotive etc.) have well established practices. Furthermore, applying "hardware in the loop" to simulation and validation of digital systems in dependent on the quality of the digital simulation model which can be difficult for waterborne transport due to the variability of ship designs, complexity and lack of relevant data concerning the integrated components. Pre-delivery testing and sea trials could include fault simulation and digital testing founded upon the identification of critical digital systems identified by the HAZOP, yet such trials focus on hardware or subsystems such as rudder control rather than addressing the entire integration. For safety critical systems, reliability regimes needs to be established so as to identify the safe default state in case of system failure or the identification of malicious intervention, in this respect the best system state could for example be: "fail operational", "fail soft", "fail safe", "fail secure", "fail passive", "be fault tolerant".

Activities will address the development of a HAZOP methodology for whole system assessment of highly digitised, connected complex vessels. The methodology shall include system, system of systems designed for specific function or sets of functions and/or a methodology for the entire vessel, including when application of artificial intelligence algorithms are foreseen. The methodology will be developed with relevant stakeholders including shipbuilders, system designers and equipment providers, IT professionals, operators, class societies, regulators. Work will draw upon the expertise of other sectors with more developed procedures for the assessment and assurance of digital safety.

On-board systems and functions integration by design, for safe and secure operation should be used to test and demonstrate the safety and security of the applications.

The developed methodology will be applied to a representative complex highly digitised vessel, safety critical systems and functions will be identified and appropriate reliability regimes and mitigation measures established with consideration of both malicious intervention and system failure.

Cost effective methodologies for validating the safety, resilience and correct functioning of digital and connected safety critical ship systems, including system of systems, will be developed and demonstrated. In case of validation on the basis of a theoretical digital models and/or digital twinning (e.g. hardware in the loop) then the validity of the model should be proven as well as its flexibility to be applied towards a range of vessel designs. In case of validation on the basis of physical testing of the responses of the final system to a range of fault conditions and malicious interventions during the final trials, there should be assurance that test conditions are representative of the identified risks. Guidance shall be produced and disseminated concerning the recommended methodology for assuring the safety and resilience of complex digitalised and connected shipping.

The safety assessment shall be developed by using methodologies suitable for being assessed in international fora such as the International Maritime Organization.

Aviation Safety and Resilience

D6-3-7. Aviation safety - Uncertainty quantification for safety and risk management (2023)

Specific conditions	
Expected EU contribution per project	The Commission estimates that an EU contribution of XX million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Indicative budget	The total indicative budget for the topic is EUR XX million.
Type of Action	Innovation Action
Eligibility	Activities are expected to achieve TRL 4-6 by the end of the project –

conditions	see General Annex B.

Expected Outcome: Project results should focus to the quantification of uncertainty (UQ) in all aspects of the design, manufacturing and operations for achieving high level of safety and a better management of risks. Project results are expected to contribute to at least three (or more) of the following expected outcomes:

- UQ for modelling/simulation of design, manufacturing and integration processes.
- UQ for operational aspects.
- UQ for virtual certification.
- Big data processing and data science for safety intelligence and risk management.
- Development of UQ (as open as possible) mathematical libraries and management Tools (e.g. tolerancing, kriging, higher order reliability methods).
- Validation campaigns in challenging test cases.

Scope: Uncertainties are always present due to limited manufacturing precision and variable operating conditions and life cycle events. Integrating these uncertainties into the design process of aircraft, aircraft engines and systems is a key element to reduce program risk and to ensure safe and economic operation.

Uncertainty is an upper bound between the estimate of aircraft characteristics and performance at a certain stage of its development and characteristics of the aircraft once in service. As such, the full lifecycle of aviation systems should be taken into account, including uncertainties occurring during operations. This uncertainty can be the consequence of the quality of the means used during the development phase to estimate these characteristics and an inaccurate knowledge of the actual status of the aircraft, and appropriate tolerancing in the design phase.

Evaluation of uncertainties associated to each measurement should be the result of a detailed and justified methodology. Treatment of uncertainties enables a rigorous management of performance engagements and associated risks assessment. Traditional safety margin approaches will be replaced by engineering procedures based on sound mathematical basis.

As appropriate, safety risk assessment should be addressed in cooperation with EASA, notably with regard to big data processing on safety intelligence.

Cross-cutting

D6-4-1: Support for dissemination events in the field of Transport Research (2023)

Indicative budget: The total indicative budget for the topic is EUR XX million.

Type of Action: Coordination and Support Actions

Expected Outcome: Project's results are expected to contribute to all of the following expected outcomes:

- Higher visibility, political and strategic relevance of the transport sector and of the EU policy in the field;
- Enhanced dissemination, communication and valorisation of transport R&I objectives, perspectives, strategies and results;
- More effective links and exchanges between research and innovation stakeholders and policy makers, to support the development and deployment of innovative solutions in Europe;
- Increased attractiveness of transport related studies and reinforce the pursuit of excellence in European transport research and innovation, by giving recognition and visibility to the best achievements.

Scope:

Actions should address the activities of both Part A and Part B:

Part A: The action will prepare and provide support to the Transport Research Arena conference (TRA) to be organised in 2026 gathering transport stakeholders for discussing political, industrial and research issues on a European and global level.

Proposals are expected to demonstrate the financial and organisational support of the national authorities' and a preliminary economic plan covering the additional funding needs. In order to ensure high political and strategic relevance, preference will be given to proposals involving Member States holding the Presidency of the European Union in year 2025, 2026 or 2027.

In line with previous TRA biannual conferences, the event should address the technological and industrial developments of the transport sector (road, rail, waterborne, aviation sectors and cross-modal aspects) providing a high level, future oriented perspective coming from politics, the industry and the research community, in response to Europe's social needs and expectations.

In collaboration with the relevant actors, such as the European Commission services, the different European Technology Platforms (ERTRAC for road, ERRAC for rail, WATERBORNE TP for waterborne, ALICE for logistics and ACARE for aeronautics and ECTP for construction), the Conference of European Directors of Roads (CEDR), the

European Transport Research Alliance (ETRA) and the previous TRA conference organisers in order to maintain continuity, the action will define the overall planning of the conference, structure the technical and political sessions of the event, contribute to select the appropriate location for the venue and offer operational IT tools for the registration of participants, the handling of speakers' contributions, contribute to the organisation of logistics, etc. Support to the organisation of demonstration activities should also be foreseen.

Specific attention should be put on a broad and balanced participation i.e. students, young researchers, women, a large number of countries' representatives, etc.

Part B: The proposal is expected to also organise two competitions for transport research and innovation awards covering all transport modes and cross-cutting issues (technological, socio-economic and behavioural aspects) in line with the EU policy objectives for climate-neutral and environmentally friendly mobility:

- A competition for students and young researchers with the goal of stimulating the interest among young researchers/students in the field of transport;
- A competition for senior researchers in the field of innovative transport concepts based on results from EU-funded projects only.

The organisation of these awards should ensure high-quality competition and very good media coverage before, during and after the TRA conference, in line with previous editions (TRA Visions). The competition is expected to give particular attention to gender issues.

OTHER ACTIONS NOT SUBJECT TO CALLS FOR PROPOSALS

Grants to identified beneficiaries

1. Continuation of the Transport Research and Innovation Monitoring and Information System

TRIMIS was announced by the Commission's "Europe on the Move" Communication in May 2017, as an important instrument for assessing technology trends and research and innovation capacities in the transport sector. Since its launch in September 2017, it has been serving as a one-stop-shop that gathers, analyses and provides open-access information on transport research and innovation activities at EU and Member State level. TRIMIS is providing up to date, reliable information and analyses in support of the research community, transport stakeholders and policy makers, facilitating exchanges between partners and informing decision making processes. It is also acting as a monitoring system of progress against agreed targets and roadmaps, notably towards the delivery of the European Green Deal, EU's Sustainable and Smart Mobility Strategy and Fit for 55 targets.

The current operating horizon of TRIMIS is until 2024 and this action will enable its continuation beyond that timeframe. In particular, it will allow to capture in the database and analyses of TRIMIS the results of EU-funded and Member State projects available after 2024 (including from the Horizon 2020 Green Deal Call). Furthermore, this action will enable to expand the work of TRIMIS, developing new analyses, technology assessments and recommendations for future Research & Innovation and policy action. Finally, the extension of TRIMIS will allow the continuous monitoring of strategic transport research and innovation agendas, with Key Performance Indicators to track progress against targets, as well as reporting on the progress of innovation and implementation, following the funding support provided by Horizon Europe and other programmes.

Type of Action: Provision of technical/scientific services by the Joint Research Centre

Indicative timetable: 2nd quarter of 2024 for the Administrative Arrangement

Indicative budget: EUR XX from the 2024 budget

2. Support for the SET Plan Conference in 2023

Spain will organise the annual Strategic Energy Technology Plan conference in 2023. The conference will take place in–Spain during the Spanish–Presidency of the Council of the European Union. The European Commission will support the organisation of the annual SET Plan conference in cooperation with the entity designated by the Spanish Presidency This grant will be awarded without a call for proposals according to Article 195(e) of the Financial

Regulation and Article 20(4) of the Horizon Europe Framework Programme and Rules for Participation to the legal entity identified below as it is responsible for energy policy and will lead all activities on energy policies during the time of Spanish Presidency of the Council of the European Union. As such, the co-organisation of SET Plan Conference falls under its competence.

Legal entities: TBC

Form of Funding: Grants not subject to calls for proposals

Type of Action: Grant to identified beneficiary according to Financial Regulation Article 195(e) - Coordination and support action The general conditions, including admissibility conditions, eligibility conditions, award criteria, evaluation and award procedure, legal and financial set-up for grants, financial and operational capacity and exclusion, and procedure are provided in parts A to G of the General Annexes.

Indicative timetable: 4th quarter of 2023

Indicative budget: EUR XX million from the 2023 budget

3. Support for the SET Plan Conference in 2024

Hungary will organise the annual Strategic Energy Technology Plan conference in 2024. The conference will take place in Hungary during the Hungarian Presidency of the Council of the European Union. The European Commission will support the organisation of the annual SET Plan conference in cooperation with the entity designated by the Hungarian Presidency This grant will be awarded without a call for proposals according to Article 195(e) of the Financial Regulation and Article 20(4) of the Horizon Europe Framework Programme and Rules for Participation to the legal entity identified below as it is responsible for energy policy and will lead all activities on energy policies during the time of Hungarian Presidency of the Council of the European Union. As such, the co-organisation of SET Plan Conference falls under its competence.

Legal entities: TBC

Form of Funding: Grants not subject to calls for proposals

Type of Action: Grant to identified beneficiary according to Financial Regulation Article 195(e) - Coordination and support action The general conditions, including admissibility conditions, eligibility conditions, award criteria, evaluation and award procedure, legal and financial set-up for grants, financial and operational capacity and exclusion, and procedure are provided in parts A to G of the General Annexes.

Indicative timetable: 4th quarter of 2024

Indicative budget: EUR XX million from the 2024 budget

4. Placeholder: Clean Energy Transition co-funded Partnership

5. Placeholder: Driving Urban Transition co-funded Partnership

Public procurements

1. Study on how to mobilize industrial capacity building for advanced biofuels

Based on the assessment of the industrial capacity needs and potential of the WP 2021 tender study and the road map for building it, this study will identify and propose ways to realize the industrial value chains, including financial, technical, business and feedstock related

Form of Funding: Procurement

Type of Action: Public procurement

Indicative timetable: 2nd quarter 2023

Indicative budget: EUR XX million from the 2023 budget

2. Technical support for low carbon and renewables policy development and implementation

Provision of technical support for the development and implementation of policies related to low carbon and renewable energy. The main base will be the recast of the renewables directive 2018/2001, as well as preparatory actions linked to the European Commission proposals for the amended renewable directive 2021/0218 (COD) and the hydrogen & decarbonised gas market package [References to be added after 15th December 2021].

This would include studies on sustainability, certification, climate impacts, industry competitiveness, consumer information, and facilitation of standardisation. Furthermore, communication activities that enable stakeholder engagement can be supported.

Type of Action: Public Procurement – using direct service contracts or existing framework contracts.

Indicative timetable: 2 contracts in 2023, 2 contracts in 2024.

Indicative budget: EUR XX million from the 2023 budget and EUR XX million from the 2024 budget

3. Development of tools and indicators for monitoring the renewables industry ecosystem

This action comprises research activities that collect data, develop indicators, provide descriptive statistics, and present online visualisation tools or dashboards, with the overall scope to improve monitoring of progress in the renewables industry ecosystem. The sectoral coverage of EU's renewables industry ecosystem will draw on the definitions pursued in the Commission's Annual Single Market Report 2021, covering energy supply, manufacturing of equipment, and other upstream and downstream activities along the industry's value chain, and having as a starting base Eurostat data. However, this research action would require exploring additional sources, approaches or techniques, in order to deliver the necessary level of granularity, across the various elements of the respective industrial ecosystem and across EU Member States.

The scope of this action is fourfold:

1) First, it seeks to adopt a multidimensional approach to depicting performance trends in renewables industry for the EU and across Member States that include, in addition to greenhouse gas emission reductions: its economic expansion; competitiveness; circularity; environmental sustainability; social inclusiveness; and resilience.

2) Second, monitoring, assessment, and visualisation elements will also cover the bottlenecks or barriers impeding the development of the renewables industry ecosystem, as well as the enabling conditions or inputs needed in order to accelerate its progress.

3) Third, it would place EU's renewables industry within an international comparison perspective, as well as in a contrastive stance with the fossil-fuel industry.

4) Finally, this research action would keep track of the respective tendencies vis-à-vis targets and visions as expressed under the European Green Deal and EU's new Industrial Strategy, and consider an alert mechanism or criteria for signalling when worrying trends are observed or anticipated.

Results of this action should contribute to all of the following expected outcomes:

- Systematic data collection and provisions of indicators that allow for the monitoring of the multidimensional performance of EU's renewables industry ecosystem at the required disaggregated sectoral level and across Member States.

- The generation of comprehensive, analytical reports discussing observed trends and results, as well as of policy briefs and / or executive summaries capable of reaching a wide audience.

- Appealing, accessible, and easy to understand visualisations for monitoring key trends in the renewables industry ecosystem.

Budget: XX EUR from the XX budget

4. Quantification of the environmental impact and energy consumption of ICT

Research from academic institutions and environmental organization should provide a reliable overview, based on a solid and transparent methodology about the environmental impact and energy consumption of ICT systems

- in terms of the quantification of the total impact
- in terms of the breakdown of this impact into its main components (manufacture of devices, use of devices, networks, cloud computing, etc.)
- in terms of historic and projected evolution of these impacts (in particular in view of the projected increase in the use of edge computing, as well as the uptake of the 5G technology whose impacts on the energy efficiency and overall energy consumption of ICT systems (including rebound effects) would merit further investigation).

Budget: XX EUR from the XX budget

5. Extension of the METIS energy model in terms of market design, demand sector granularity and interface with regions outside of Europe.

METIS is a mathematical model providing analysis of the European energy system for electricity, gas and heat. It simulates the operation of energy systems and markets on an hourly basis over a year, while also factoring in uncertainties like weather variations. The model also explicitly represents electricity transmissions and distribution networks. The addition of hydrogen as an energy carrier have allowed using the model in the Impact Assessment for revised gas markets and hydrogen directive and regulation. Further ongoing developments address the better integration of demand with supply sectors and a finer regional granularity.

In order to secure the model for the in future policy cycles, extensions would be necessary along the following three dimensions:

1. A representation of energy markets including the behaviour of participants
2. The inclusion of all demand sectors including a linkage of demand in these sectors to economic activity as represented by macro-economic models
3. The interaction with energy systems outside of the EU that have a key impact on the EU energy system, e.g. via exports of electricity, gas and hydrogen.

Budget: EUR XX Mio

6. Quantification of the environmental impact and energy consumption of ICT

Research from academic institutions and environmental organization should provide a reliable overview, based on a solid and transparent methodology about the environmental impact and energy consumption of ICT systems

- in terms of the quantification of the total impact (e.g. energy consumption, GHG emissions, air pollutants, water use, raw materials use, waste produced)
- in terms of qualitative assessment of other impacts (e.g. biodiversity, ecosystem services)
- in terms of the breakdown of this impact into its main components (manufacture of devices, use of devices, networks, cloud computing, etc.)
- in terms of historic and projected evolution of these impacts (in particular in view of the projected increase in the use of edge computing, as well as the uptake of the 5G technology whose impacts on the energy efficiency and overall energy consumption of ICT systems (including rebound effects) would merit further investigation).

Budget : EUR XX million

7. Development of standardisation methods for Eco-design and Energy Labelling of photovoltaic products

Research activities for the development of standardised (pre-normative) methods relevant for ecodesign and energy labelling of photovoltaics. In particular, there would be two sets of methods developed 1. Standardised method for the calculation and testing of the yield of bifacial photovoltaic modules and 2. standardised method for the measurement and testing of the long term degradation of the photovoltaic modules performance (some activity started with the preparation of the IEC 63209 standard). The main aspects of interest (e.g. thermal fatigue, damp heat, etc.) should be identified.

The research activities should cover at least:

- Characterization (e.g. insulation test, wet leakage current test) and stabilization techniques to be applied;
- Procedure for the collection of testing samples;
- Definition of the testing protocols, testing sequence and, when applicable, pass criteria, related to the various aspects of interest (e.g. thermal fatigue, damp heat, etc.).

The overall duration of the testing process should also be analysed, with the aim of minimising it, while keeping a minimum defined level of confidence in the results. This may also imply the calculation and development of correlation factors on the basis of the duration of the testing process.

Budget: EUR XX from the 2023 budget

8. Development of a recyclability index for photovoltaic products

Research activities for the development of a recyclability index for photovoltaic modules, to be built up starting from the general methods laid down in the horizontal standards developed under M/543 and under ecodesign and energy labelling regulatory framework.

The research activities should cover at least:

- Analysis of the recycling processes currently available and expected to become available in the short-middle term for photovoltaic modules;
- Identification of CRM (critical raw materials) and environmentally relevant materials present in the bill of materials of the photovoltaic module technologies currently available and expected to become available in the short-middle term;
- Analysis of the various design solutions/architectures for photovoltaic module technologies currently available and expected to become available in the short-middle term.
- Development, calibration and validation of a scoring methodology taking into account the abovementioned topics, e.g. by including the identification of:
    - Priority parts (to the extent of material relevance [CRM/environmentally relevant material] and material recyclability);
    - Key parameters for repair and upgrade;
    - Scoring framework.

Budget: XX EUR from the 2024 budget

9. Placeholder: Support to BRIDGE (and ETIP-SNET)

Subscription actions

1. Contribution to Technology Collaboration Programmes (TCPs) of the International Energy Agency (IEA)[104]

The Commission represents the European Union in the Technology Collaboration Programmes (TCPs) concluded under the framework of the International Energy Agency where it participates in activities in certain areas of energy research. The annual financial contributions will be paid to the entities responsible for managing the following TCPs:

- Geothermal;
- Bioenergy;
- Ocean Energy Systems;
- International Smart Grids Action Network (ISGAN);
- Greenhouse Gas R&D;
- Concentrated Solar Power;
- Photovoltaic Power Systems;
- Solar Heating and Cooling;
- Clean Coal Centre;
- Wind Energy Systems;
- Renewable Energy Technology Deployment;
- Hydropower;
- Gas and Oil Technologies;
- Energy Efficient End-Use Equipment (4E);
- Clean Energy Education and Empowerment (C3E).

Type of Action: Subscription action

Indicative timetable: as of 1st quarter 2023, as of 1st quarter 2024

Indicative budget: EUR XX million from the 2023 budget and EUR XX million from the 2024 budget

[104] This activity directly aimed at supporting the development and implementation of evidence base for R&I policies and supporting various groups of stakeholders is excluded from the delegation to Executive Agencies and will be implemented by the Commission services.

2. Subscription of the EU to the Intergovernmental Panel on Climate Change (IPCC)

3. Placeholder: IRENA - Clean Energy Innovation Analysis & RE-MAP grants

4. Placeholder: Support to the IEA's Clean Energy Transition Programme (CETP) for emerging economies

5. International Partnership for Hydrogen and Fuel Cells in the Economy

The Commission represents the European Union in the International Partnership for Hydrogen and Fuel Cells in the Economy. The annual financial contribution will be paid to the entity responsible for managing it.

Type of Action: Subscription action

Indicative timetable: as of 1st quarter 2023, as of 1st quarter 2024

Indicative budget: EUR XX million from the 2023 budget and EUR XX million from the 2024 budget

6. IEA (EE HUB)

The purpose of the International Partnership for Energy Efficiency Cooperation (IPEEC) is to strengthen international cooperation on energy efficiency. The action carried out under the auspices of the Partnership should result in more effective energy policy and programme output, in best practices being more widely known, disseminated and applied and in economies of scale. The aim of the Partnership is to offer a topic-driven, structured dialogue and an operational network for enhanced cooperation and exchanges on energy efficiency between countries and international organisations by:

exchanging information and experience on development of regulatory measures, policies and programmes;

- developing benchmarks and sharing information on goods and services, along with measurement methods regarding energy performance and energy savings;
- strengthening information, education and training for energy consumers;
- building stakeholder capacity by improving contacts between national, regional and local authorities and other relevant partners and stakeholders, exchanging views and sharing knowledge and experience.

Type of Action: Subscription action

Indicative budget: EUR XX million from the 2023 budget and from the 2024 budget

7. Contribution to the International Renewable Energy Agency

The European Union is a member of IRENA. According to the organisation's Statute and Financial Regulation this implies the obligation to pay an annual contribution to its budget covering the participation of the EU in IRENA's activities. IRENA's main objective is to disseminate best practices in the field of renewables as the principal platform for international cooperation in the field, a centre of excellence on renewable energy and a repository of policy, technology, resource and financial knowledge. This includes:

The promotion of the widespread and increased adoption and the sustainable use of all forms of renewable energy globally, including in the EU, in particular to bring down costs and also to increase market experience, in order to contribute to economic growth and social cohesion as well as access to and security of energy supply;

Support activities for countries in their transition to a renewable energy future;

Reducing of barriers for renewable energy, stimulating best practice and raising awareness.

Type of Action: Subscription action

Indicative budget: EUR XX million from the 2023 budget and EUR XX million from the 2024 budget

<u>Scientific and technical services by the Joint Research Centre</u>

<u>Indirectly managed actions</u>

1. Contribution to InvestEU blending operation under the Green Transition product

The ‘Fit for 55’ package of measures adopted by the Commission in July 2021 sets out the policies and legislation for the EU to meet its 2030 target of 55% net greenhouse gas emissions reductions, which will create new opportunities for investment in new technologies and approaches. The final aim is decarbonising the economy in line with the objectives of the Paris Agreement, the European Green Deal and the European Union’s 2050 net-zero target, and Climate Law. That is why the European Commission intends to establish an efficient framework to identify European projects deploying innovative technologies, business models and approaches to reduce the green premium – the difference between the price of a carbon-emitting technology and its clean alternative. Under existing initiatives, the Commission has already been supporting, under InnovFin and other EU programmes, a variety of technological pathways for decarbonisation. InnovFin Energy Demonstration Projects[105], in particular, has been very effective at mobilising finance for first-of-a-kind projects in the area of innovative renewable energy production, storage and smart grids. It has mobilised so far EUR 346 million of EU support for 11 operations (with total project costs of EUR 864 million).

The blending operation will target projects at TRLs 6-8 via the European Investment Bank (EIB) or other implementing partners' financial instruments, by providing loans and quasi-equity (or a combination of both), which may be blended with non-reimbursable components. The financial instrument component of operations may draw from the Innovation Fund, this Horizon Europe action, or the InvestEU budget, while the non-reimbursable component will only be funded by this Horizon Europe action – to be spent economically as a last resort option to enable project's financial closure.

The blending under the InvestEU's Green Transition product focusses on the following four areas that are underrepresented in the current portfolio of InnovFin:

- *Renewable hydrogen*. In July 2020, the Commission adopted the Hydrogen Strategy[106] with the aim of decarbonising its production and to expand its use to store, transport and accelerate the use of renewable energy, as well as replacing fossil fuels in specific sectors, aiming to reach 40 GW of electrolyser capacity by 2030, producing up to 10 million tonnes of renewable hydrogen. Investments in renewable hydrogen production capacity are estimated at EUR 180-470 billion in the EU until 2050. The strategy identifies as a clear priority the production of renewable hydrogen, i.e. hydrogen produced through electrolysis using renewable electricity. In this context, a top priority is to demonstrate larger size, more efficient and cost-effective electrolysers, with capacities reaching 100 MW and above. Another priority is to further develop large scale hydrogen end-use applications, notably in industry. The path to business case feasibility (without any grant component) of the solution at potential replication sites shall also be investigated. The necessary coordination, along the value chain with the European Clean Hydrogen Alliance[107], and on data and knowledge with the observatory and data base in the Clean Hydrogen Joint Undertaking, is foreseen.

- *Sustainable aviation fuels (SAF).* Though aviation accounted for only 3.7% of total CO_2 emissions in the EU in 2018, it accounted for 15.7% of CO_2 transport emissions. Aviation is the second highest transport sector after road vehicles, and the fastest growing. Reducing aviation emissions is challenging considering the long operational

105 https://www.eib.org/en/products/mandates-partnerships/innovfin/products/energy-demo-projects.htm

106 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0301

107 https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en

life of aircraft and the fact that that zero-emission aircraft configurations and powertrain options for commercial air transport are far from technological and commercial maturity. SAF can significantly reduce aviation reliance on fossil fuels, while relying on existing infrastructure and propulsion systems, but the transition will require significant investments. While several SAF production pathways are certified, their use in the fuel mix is still negligible (less than 0.1%) due to high production costs. The price of the most innovative and sustainable types of fuels is estimated at up to 3 to 6 times the price of fossil aviation fuels depending on the production pathway, while their lifecycle emissions savings are 85% or more compared to fossil fuels. The path to business case feasibility (without any grant component) of the solutions at potential replication sites shall also be investigated as well as sustainability in wider scale as part of the Fit for 55 package. The Commission has therefore proposed the ReFuelEU Aviation initiative[108] to boost the supply and use of sustainable aviation fuels in the EU. The action will support the development of the most innovative SAF *notably advanced biofuels and RFNBOs*[109] in line with the ReFuelEU Aviation and Renewable Energy Directive sustainability framework.

- *Long duration energy storage (LDES)*. At any moment in time, electricity consumption and generation have to be perfectly matched. This balance is necessary not only in the short term for power grid stabilisation (for which short duration storage solutions exist), but also over the long term, to ensure supply adequacy, by compensating for fluctuations, for meteorological dark and still periods ('dunkelflaute') that can last a few weeks, and for seasonal variations between summer and winter. Long duration – weekly to seasonal - renewable grid scale energy storage needs will expand as both the electrification of demand and the share of renewable – and variable as well as distributed - energy sources in the total supply mix will grow. Sustainable long duration energy storage therefore has a key role to play in the transition towards a carbon-neutral economy. The storage system needs to be optimised for large capacity and long duration (weekly, seasonal), for minimal climate and environmental footprint over the full life cycle, for regulatory compliance and for financial viability (hence maximising round trip efficiency, minimising costs and identifying a business case for the targeted investment based on electricity storing / de-stocking price projections). The path to business case feasibility (without any grant component) of the storage solution at potential replication sites shall also be investigated. Sustainable storage solutions for renewable energy, involving an energy vector that can be used for other purposes than regenerating electricity are also eligible. The topic is open to all technologies: chemical (including hydrogen and its derivatives), electrochemical, thermal and mechanical technologies (other than pumped hydro which is mature and available commercially).

[108] Commission proposal for a Regulation of the European Parliament and the Council on ensuring a level playing field for sustainable air transport (COM(2021) 561 final, 14 July 2021, 2021/0205 (COD))

[109] Renewable Fuels of Non Biological Origin (RFNBOs) as defined under RED II.

- *Direct air capture (DAC) of CO_2*. European Commission scenarios reaching net-zero emission by 2050 show extensive use of carbon dioxide removal, including DAC. For example, the 1.5 tech scenario forecasts 266 Mt of CO_2 point capture and 200 Mt of CO_2 DAC. Most IPCC scenarios modelling 1.5°C paths also include a share of carbon dioxide removal (with and without DAC). DAC emerges as the most relevant source of carbon for renewable power-to-fuels/chemicals processes in such scenarios, but several challenges remain for a large-scale deployment of the technology. The future operational and financial viability (without any grant component or support scheme) of any DAC solution at potential replication sites shall also be investigated in function of the fate of the captured CO2 (i.e. underground storage or use), renewable energy source used for the capture process, and vicinity to CO2 transport and storage infrastructure (in case of underground storage). The International Energy Agency estimates the current DAC cost to be within a wide range of \$100-\$1000 per captured tonne of CO_2. Stakeholders claim that costs can be reduced to €50-€100 by 2030 with sufficient investments in R&I and deployment. As there is so far no specific EU initiative targeting DAC, this topic will fill an important gap.

Functioning of the blending operation

The blending operation will be open to all applicants meeting the set eligibility criteria set in this text and InvestEU Green Transition product. As such, it is not restricted to projects proposed under pre-existing or future partnerships with the European Commission. This blending operation is particularly relevant because it seeks to bring together the public and private sector to fund pre-commercial, industry-scale demonstration projects for critical decarbonisation technologies, directly addressing the early deployment funding gap for the selected technologies and provide a structure to accelerate their commercialisation.

Projects' selection and financing procedure follows the InvestEU Regulation. In particular, the EIB or other implementing partners will check the financial viability of and perform full due diligence on each potential financing operation, while the Commission services assure their eligibility under the 'policy check' procedure. Special attention shall be paid to ensuring that the technologies developed and Intellectual Property generated will benefit the EU interest, in particular by focussing the funds on high quality projects realised in the Union/ eligible Associated Countries.

Expected impact

Unprecedented investment is needed to turn climate policy targets into reality. Attaining the 2030 target of at least 55% net emissions reduction is estimated to require EUR 350 billion of additional annual investment. Blended finance is a crucial tool to mobilise urgently needed private 'patient capital,' especially in domains considered too risky for the markets to function. This is the case of the technologies selected, which will benefit from investments in demonstration and scaling-up – leading to increased confidence among market participants, economies of scale in production and deployment, and significant cost reductions. The project pipeline of the InnovFin EDP and FutureMobility facility, as well as the high number of submitted proposals under the first Innovation Fund calls, indicate the richness of the EU ecosystem, which - boosted by the fit-for-55 package - is expected to thrive in the coming years. The initiative will accelerate the reduction of the green premium in key areas, allow for wider, faster up-take and contribute to the creation of jobs in the EU in green industries manufacturing these solutions.

Legal entities:

European Investment Bank (EIB), 98-100, boulevard Konrad Adenauer, L-2950 Luxembourg, Luxembourg, as the implementing partner under InvestEU

Form of Funding: Indirectly managed actions

Type of Action: Indirectly managed action

Indicative timetable: as of 1st quarter 2023 and 1st quarter 2024

Indicative budget: EUR XX million from the 2023 budget and EUR XX million from the 2024 budget

Expert contract actions

1. Experts for the monitoring of actions

This action will support the use of appointed independent experts for the monitoring of actions (grant agreement, grant decision, public procurement actions, financial instruments) and where appropriate include ethics checks.

Form of Funding: Other budget implementation instruments

Type of Action: Expert contract action

Indicative timetable: As of 1st quarter 2023 and as of 1st quarter 2024

Indicative budget: EUR XX million from the 2023 budget and EUR XX million from the 2024 budget

2. External expertise to advice on EU research and innovation policy

This action will support the provision of independent expertise in support of the design, implementation and valorisation of EU research policy. Individual experts will work in the following domains:

- Analysis, design, assessment and implementation of strategic climate, energy and mobility research and technology options and actions
- Future climate, energy and mobility -related research actions and programmes, contribution to their impact assessment.
- International cooperation in the field of climate, energy and mobility research and innovation.
- Analysis and valorisation of EU climate, energy and mobility research results in view of contributing to the elaboration of policy reports (such as projects for policy, project cluster reports, etc.).
- Preparation of actions for Horizon Europe missions.

The tasks of individual experts would include:

- Analysis of the contribution of the funded research to the EU policy objectives spanning across all climate, energy and mobility modes and systems;
- Analysis of the state-of-the-art at international level; investigation of deployment options for the developed knowledge;
- Participation in international symposia, including the drafting of White Papers and reports on the symposia's conclusions;
- Advise the Commission on promising technologies covered by European and nationally funded projects and on ways to stimulate synergies;
- Assist the Commission in the evaluation of calls for expression of interest.

In addition to individual experts, this action could provide for Commission expert groups.

Form of Funding: Other budget implementation instruments

Type of Action: Expert contract action

Indicative timetable: As of 1st quarter 2023 and as of 1st quarter 2024

Indicative budget: EUR XX million from the 2023 budget and EUR XX million from the 2024 budget