Horizon Europe

Draft Work programme 2021-2022

Cluster 5 ('Climate, Energy and Mobility')

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Please note that:

- This document is **work in progress and subject to changes.**
- Due to the on-going negotiations of the Budgetary Authority on the budget 2021-2027, **all topics included in this document are subject to budget availability.** Topics may be withdrawn in case of lack of budget.
- This document does not yet reflect activities to be supported by **Horizon Europe Missions**, and cluster 5 activities in support of HE Missions.
- The **call structure** still needs to be defined. The call structure will impact the structure of the WP document.

DISCLAIMER

This draft has not been adopted or endorsed by the European Commission. Any views expressed are the preliminary views of the Commission services and may not in any circumstances be regarded as stating an official position of the Commission. The information transmitted is intended only for the Member State or entity to which it is addressed for discussions and may contain confidential and/or privileged material.

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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.

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 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 Commission's strategic vision "A Clean Planet for All"[3] outlines that the move to climate neutrality – along with faster digitalisation and accelerated economic and societal changes – will transform the energy and mobility sectors in the coming decades making them increasingly intertwined. Research and Innovation will heavily influence the speed at which these transitions can take place, directly affecting the associated costs, impacts and co-benefits, such as better air and water quality, increased employment, social inclusion, sustainable resource management (including the circular economy and biodiversity), and reduced dependency on fossil fuels. Beyond the inevitable social transitions and lifestyle changes, a key contribution to success is the development of a wide portfolio of – from a life-cycle perspective – cost-effective climate neutral alternatives for emitting activities, based on often in combination with enhanced sector coupling, digitalisation, system integration and leveraging, whenever appropriate, the existing Earth observation and monitoring programme Copernicus.

The rate at which European research and innovation actions succeed in developing, upscaling, implementing, and commercialising such innovative solutions will steer EU's future competitiveness of its existing and newly emerging industries in European and global markets.

Cluster 5 supports the EU's strategic objectives through activities included in this work programme and through the support of Institutional European Partnerships[4] which are implemented through dedicated structures. Although the latter activities are not included in

[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
A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy; COM/2018/773 final
[4] Clean Hydrogen, Transforming Europe's rail system, Integrated Air Traffic Management, Clean Aviation

this work programme, it is of great importance to maximise synergy and coherence between activities regardless of their implementation mode[5].

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 by leading the development of key digital and enabling 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 led 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)**
i. **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.**	1. Climate sciences and responses
ii. **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
iii. **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
iv. **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
v. **Towards climate-neutral and environmental friendly mobility through clean solutions across all transport modes while**	5. Clean and competitive solutions for all transport

[5] 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

increasing global competitiveness of the EU transport sector.	modes
vi. **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 research and innovation support programme in a system of European and national funding programmes that share 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. 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 ERDF, ESF+, JTF, EMFF, EAFRD and InvestEU), 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 ine with regional/national smart specialisation strategies. It can support 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) [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.

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[6] Initiative, which was launched at COP21 and currently

[6] http://mission-innovation.net/our-work/innovation-challenges/

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 on renewable energies[7], in line with the spirit of the Paris Agreement which emphasises the need for global cooperation on technology development and transfer.

Activities included in this work programme have been **designed together** with EU Member States, EEA Countries and the European Parliament, as well as stakeholders and interested citizens.

[7] Topics C5-D3-RES-01-2021 and C5-D3-RES-29-2022

Destination 1 – Climate sciences and responses

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.

Building user-oriented and user-driven knowledge, supported by a broad range of methodologies including improved and new high-resolution and integrated models will inform human response to global change on all levels. Further study on the interactions between climate change and ecosystems is essential for a more complete understanding of the Earth system and the effective deployment of solutions, including ecosystem-based ones, within the climate and planetary boundaries. Furthermore, incorporating and further advancing research in social sciences and humanities, and behavioural science methodologies, and enabling citizens, end-users and other stakeholders, including the private sector and small and medium-sized enterprises, to contribute to research and co-create innovative solutions, will accelerate societal transformation, behavioural change and institutional development, and thus enable an efficient and just transition integrating the social aspects of sustainability.

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.

Proposals for topics under this Destination should set out a credible pathway to contributing to **all** of the following **expected impacts**:

a) Advancing knowledge and providing solution in the any of following areas: Earth system science; pathways to climate neutrality; climate change adaptation including climate services; social science for climate action; and better understanding of climate-ecosystems interactions.

b) Contributing substantially to key international assessments such as the Intergovernmental Panel on Climate Change (IPCC).

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 between activities supported under Destination 1, as well as in other Destinations and Clusters, and in particular complementaries 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 Destination 1 concentrates on activities related to climate science and modelling, whereas Cluster 6 contributes to R&I on the implementation of climate change mitigation and adaptation solutions in the areas covered by Cluster 6.

When relevant for topics related to modelling activities under Destination 1, proposals should ensure, on request, full royalty free access (under confidentiality clause) for Union Institutions, bodies, offices or agencies for developing, implementing and monitoring Union policies or programmes, to all the tools and instruments necessary to reproduce and validate research results generated by the action (including access to data and model code).

Earth system science

C5-D1-CSR-01-2021: Improved understanding of greenhouse gas fluxes and radiative forcers, including carbon dioxide removal technologies

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of up to EUR 8 million would allow these outcomes to be addressed appropriately.
Type of action	Research and Innovation Action
Procedure	To ensure a balanced portfolio covering all three areas, grants will be awarded to applications not only in order of ranking but at least also to one project that is the highest ranked within each area, provided that the applications attain all thresholds.

Expected outcomes:

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

- Improved knowledge in the addressed areas, also through increasing the use of high quality data, leading to a better understanding of the processes driving climate change.
- Contribute to improved projections of climate change (including in relation to climate change-related extreme events).
- Improve our understanding of how innovative mitigation actions can help stabilise global temperature.
- Improved understanding from these actions should be fed into improvements in Earth system models, climate services and other forms of downstream use.

Scope:

This topic aims at filling fundamental gaps in our understanding of Earth system, focussing on greenhouse gas fluxes and Earth system feedbacks, the behaviour of radiative forcers (including their pre-cursors), and efforts to stabilise global temperature through deployment of carbon dioxide removal approaches.

Beneficiaries are encouraged to take advantage of the relevant national and/or European research infrastructures (e.g. ICOS, ACTRIS etc.).

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

a) Greenhouse gas fluxes and Earth system feedbacks

Actions should target a better understanding of key processes related to the life cycles of greenhouse gases, other climate forcers and associated feedbacks affecting the Earth's climate over different time horizons, including the effect of climate variability from inter-annual to multi-decadal and longer time scales. Actions should focus on elements of the climate system, including for example terrestrial ecosystems, hydrological cycles, ocean circulation changes, coastal zones or the biogeochemical cycles, which have an important influence on climate change and its impacts but are not sufficiently understood by the latest science.

b) Global warming contribution of different, non-CO_2 radiative forcers

Actions should improve knowledge concerning the individual and cumulative contribution of short- and long-lived radiative forcers, including greenhouse gases and their precursors, aerosols, refrigerants and other climate forcers, to climate change as well as other environmental issues. Actions may focus on a subset of forcers, and should concentrate on those where the relationship between emissions, atmospheric live-cycle and global warming is least well understood. The action should also assess the climate and non-climate impacts, over multiple time scales, of policies and measures targeting forcers other than CO_2, and the application of this knowledge in relevant sectors (such as transport, industry, agriculture and health) with view to co-benefits and trade-offs of mitigation policies with other societal benefits, including human health.

c) Climate and Earth system responses to climate neutrality and net negative emissions

Actions should improve understanding of the environmental consequences of reducing net greenhouse gas emissions to levels consistent with the aim of stopping global warming. Actions should focus on the response of global temperatures and other key properties of the Earth system to sustained reductions in greenhouse gas emissions to net zero and below. This should include, but not be limited to, pathways consistent with the Paris Agreement goals of limiting warming to well below 2°C and pursuing efforts to limit it to 1.5°C above pre-industrial levels, including scenarios with and without temperature overshoot. The action should pay particular attention to climate-related challenges at different temporal scales, including potential benefits, risks and feedbacks (like e.g. effects of surface albedo changes) of using carbon dioxide removal strategies, whether nature-based or technological, to stabilise global temperature. In this context, interaction with actions dedicated to carbon dioxide removal (like ongoing EU projects, NEGEM, LANDMARC and OceanNETs, as well as C5-D1-CSR-08-2022: Carbon Dioxide Removal approaches and Carbon Capture Utilisation and Storage ([Reference to the CCUS calls])) is encouraged.

International cooperation on the above sub-topics is encouraged. The Joint Research Centre (JRC) may participate as a member of the consortium but is not eligible for funding.

C5-D1-CSR-02-2022: Verification and reconciliation of estimates of climate forcers

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of up to EUR 5 million would allow these outcomes to be addressed appropriately.
Type of action	Research and Innovation Action

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

- Enhancing the ability to ascertain whether and to what extent emission reduction efforts are producing the desired atmospheric signals for key greenhouse gases on relevant spatial and temporal scales.
- Better understanding of apparent discrepancies between reported greenhouse gas (GHG) emissions and removals (in national inventories and other schemes), measured atmospheric signals and modelled levels, with the aim of reducing and/or reconciling them on the long run.
- Reduced uncertainty of national GHG inventories through improved comparability with models and observations and piloting top-down approaches recognised in the 2019 refinement of the IPCC 2006 Guidelines for National Greenhouse Gas Inventories.
- Contribution to improving the attribution of GHG fluxes (anthropogenic vs natural) as well as non-GHG atmospheric climate forcers (such as aerosols), including feed-backs.
- Support the Paris Agreement, in particular the Global Stocktake, and the implementation and monitoring of EU climate policy instruments.
- Provide input (such as data, models and methods) and contributions to international programmes and assessments (such as IPCC, Global Carbon Project).

Scope:

Actions should aim at reconciling national greenhouse gas inventories with relevant assessment and monitoring systems in Europe (in particular EU and Horizon Europe associated countries) including observations from a wide range of monitoring networks, in-situ and remote sensed) at a range of scales by comparing their results. Aerosols and their precursors should also be included in the analysis, as well as other air pollutants where relevant (e.g., co-emitted species).

Special attention should be given to establishing how the use of top-down techniques that can support the verification of national greenhouse gas inventories and other regulated estimates of emissions and removals, in order to improve or supplement the methods/approaches currently used. Ideally case studies in collaboration with one or more national inventory compilers should be organised for this purpose.

Proposals should aim to develop scientifically robust methodologies, building on achievements from previous research activities in order to decrease to acceptable levels uncertainties associated with emission estimates, identify and constrain irreducible differences and improve the attribution of emissions and removals to their sources (in particular the separation of natural versus anthropogenic fluxes). They should also explore and support the development and implementation of top-down approaches for use in national inventories, as recognised in the 2019 Refinement of the IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

The development and improvement of methodologies should also address the need for versatility of applications, including mobile sources, individual point sources, land, management actions etc. relevant to current and potential future reporting and compliance systems. Furthermore, issues such as data and metadata standards, transfer of information and tools, and replicability of methodologies and tools outside Europe (mainly in developing countries) should also be addressed.

Beneficiaries are encouraged to take advantage of the relevant national and/or European research infrastructures (e.g. ACTRIS etc.).

C5-D1-CSR-03-2022: Development of high-resolution Earth system models for global and regional climate change projections

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of up to EUR 10 million would allow these outcomes to be addressed appropriately.
Type of action	Research and Innovation Action

Expected Outcomes:

Proposals should improve European high-resolution, fully coupled atmosphere-ocean-land Earth System Models, able to robustly simulate key climate processes, their variability and future trends for this and well into the next century in order to enhance the quality, robustness and versatility of climate projections on a range of temporal and spatial scales (global and regional) to (1) support policies implementing the goals of the Paris agreement and (2) address the societal need to assess and respond to the adverse impacts of climate change.

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

- Improved climate projections with sound uncertainty estimates under different scenarios on different temporal and spatial scales.
- Support to adaptation strategies and policies based on a more realistic representation of climate change on regional scale with a focus on Europe, the Arctic and the Mediterranean and a better representation of extreme weather and climate events.
- Improved understanding and modelling of tipping points in the climatic systems, such as the ice shields at both poles and ocean circulation.
- Advances in attribution of climate change and its phenomena to anthropogenic forcers.
- Support to the implementation and evaluation of mitigation and adaptation solutions, including climate services, climate related disaster risk management, and linkages with Integrated Assessment Models.
- Pave the way for the next cycle of the IPCC Assessment reports by a leading role in the WCRP Coupled Model Intercomparison Programme (CMIP).
- Sustain and enhance European cooperation and leadership in climate sciences.

Scope:

Projects should foster a fully coupled atmosphere-ocean-land-ice Earth-system model approach that contribute to a better understanding and representation of the processes, including for that drive and influence climate change on global and regional scale. Arctic and Antarctic regions should be considered as key elements in global climate changes.

Projects should make efficient use of available and high quality observational data (e.g. space-based and not space based, including in-situ and paleoclimatic data) for the development of robust model validation, verification, and improve uncertainty estimation methodologies.

They should also strive to reduce uncertainty of key parameters of climate and hydrological systems.Projects should advance methods for assessing and attributing model outputs and climate change impact on regional and local scales with the support of advanced digital technologies, such as artificial intelligence methodologies.

The advanced climate modelling activities should support the attribution of observed and projected climatic hazards to climate change or climate variability.

The activities should build on the experiences from and results of other European projects contributing to the development of a new generation of climate models[8].

Beneficiaries are encouraged to take advantage of the emerging ICT infrastructures (e.g. EuroHPC and other high performance computing, cloud-based facilities) that will be made available through the Destination Earth initiative under the Digital Europe programme.

If adding value to the project outcomes, coordination with the Destination Earth initiative can be proposed to ensure the timely development of "climate replicas" building on the new state-of-the-art IT infrastructure, including access to EU high performance computing resources and an operational platform to upload and integrate the models and data developed in the course of the projects.

The high-resolution model development should be properly connected with major programmes in the domain of Earth Observation such as the Copernicus Programme, the ESA science satellite missions in Europe, and the GEO initiative at global level.

Projects are expected to co-operate with other projects funded under this call, as well as other relevant projects under Destination 1 and Cluster 6, Destination 5.

Pathways to climate neutrality

C5-D1-CSR-04-2021: Modelling the role of the circular economy for climate change mitigation

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

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

8 E.g., H2020 CRESCENDO (Coordinated Research in Earth Systems and Climate: Experiments, kNowledge, Dissemination and Outreach) https://cordis.europa.eu/project/id/641816 , H2020 PRIMAVERA (PRocess-based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment) https://cordis.europa.eu/project/id/641727, or projects funded from the call topic H2020-LC-CLA-18-2020.

- Improve existing EU and/or global climate mitigation models by better representation of basic industrial value chains (including reliable data) and potential mitigation technologies including the impact of circular economy.
- Improve the quantification of the impacts and potentials of the circular economy for climate change mitigation.
- Support the integration of the circular economy into climate action, policies and their evidence base, including externalities.
- Support the integration of the GHG emission reduction / mitigation in the circular economy criteria.

Scope:

Projects are to advance the understanding and modelling of the current and future potential contribution of the circular economy in the EU to GHG emissions reductions. The scope of the modelling activities has to go beyond the state-of-the-art, in particular in terms of sectors covered and their interrelations, be as comprehensive as possible (e.g. covering also the blue economy), and include citizen's behaviours and engagement.

This action should look beyond the specific measures needed to deliver a circular economy and propose a framework for revealing, demonstrating and quantifying the circular economy's potential contribution to climate goals, as well as improving the coverage of basic industry value chains in models (or suites of models) used to analyse mitigation pathways. The methodologies developed should assess the interrelated impacts of such policies in other environmental areas and issues as well as social and health issues, in line with the systemic approach that the European Green Deal promotes.

Collaboration between the scientific community and policy- and decision-makers in order to integrate the circular economy into integrated assessment frameworks and other comprehensive climate policy visions is highly recommended. Actions should also ensure collaboration with industry stakeholders and civil sociaty, including, for example, sharing best-practices, data, models and other knowledge required to analyse mitigation pathways to ensure the input of - and alignment with - the needs, values and expectations of society.

C5-D1-CSR-05-2021: Maximising the impact and synergy of EU climate change research and innovation

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 2 and 5 million would allow these outcomes to be addressed appropriately.
Type of action	Coordination and support action
Procedure	To ensure a balanced portfolio covering all two areas, grants will be awarded to applications not only in order of ranking but at least also to one project that is the highest ranked within each area, provided that the applications attain all thresholds.

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

- Raising awareness of citizens, business, policy-makers and other relevant audiences towards climate change, based on more efficient, transparent and engaging communication of authoritative and timely science-based information originating from EU-funded climate change research projects.
- Better coordination of both on-going and future EU-funded climate change research initiatives and a more efficient use of resources.
- Enhanced impact of research investments and accelerated transfer of knowledge to inform policy and climate actions in Europe.
- Increased robustness, coherence and visibility of the results of EU-funded climate change research and innovation leading to increased uptake of the knowledge and solutions and more robust decisions by the public sector, businesses, industry and society.
- Curation of research and innovation project results related to climate change, such that stakeholders can discover and understand what EU-funded research is ongoing in their area of interest.
- Innovative and tailor-made tools and strategies to communicate the results of EU-climate change research leading to improved science – civil society interface, while considering drivers for active citizen engagement in climate action and more sustainable behaviours.
- Better coordination of climate change research, innovation and technology initiatives within the European Research Area, facilitating complementarity and coherence between EU-level, national and regional efforts and a more efficient use of resources.
- Identification of complementary research and innovation activities among the past, present and future work supported by national and regional R&I programmes on climate change, facilitating coherence between EU-level and national efforts and a more efficient use of resources, and taking into account international developments where relevant.
- Showcasing national and regional research and innovation activities and findings that could be of interest for cooperation between countries.
- Improving prioritisation of European climate change research by identifying priority topics (in terms of knowledge gaps and/or societal needs), and taking stock of national and EU-level climate change R&I research activities, in order to enhance the ability of existing and future European R&I to respond to societal needs.
- Accelerating the transfer of knowledge on climate change research to policy-makers, practitioners and the society.
- Implementation of collaborative activities to enhance the market, regulatory or societal uptake of R&I solutions related to climate change across Europe, for example by replicating national or local success stories in Europe.
- Identify good practices at European, national and regional level on communication, dissemination and exploitation of climate change research findings and projects results and facilitate their scaling up.

<u>Scope:</u>

Actions should cover one of the following areas:

a) Maximising the impact of EU-funded climate change research

The action should deliver effective mechanisms to strengthen the science-policy and science-civil society interface on the state-of-the-art climate change research in order to increase the EU's capacity to accelerate the response to the climate crisis and, biodiversity and other environmental challenges. Climate change research is understood here as projects dealing with climate, mitigation and adaptation science that will result mainly from Destination 1 - "Climate sciences and responses"- of Horizon Europe as well as relevant legacy projects of Horizon 2020[9]. Synergies with the topic C5-D1-CSR-11-2021: Supporting and standardising climate services should be established as necessary.

Knowledge synthesis and valorisation of results across EU funded projects and initiatives are expected to constitute an important element of work and should lead to integrated policy briefs and (joint) scientific publications that consolidate findings from different projects on priority issues and challenges that are central to climate action at all scales. To deliver these objectives, the action should consider activities such as curating, clustering, co-ordinating and supporting the creation of synergies between EU-funded climate change research and innovation activities, where relevant also considering national as well as international initiatives such as Global Covenant of Mayors and Mission Innovation.

The actions should identify and systematically update research needs emerging from science and/or policy discussions, and, where possible, match these needs against the themes that are addressed (or could be addressed) by ongoing EU-funded research projects.

The action should build on the knowledge and tools accumulated during previous and existing EU-funded initiatives. It should foresee adequate resources to take over and manage selected knowledge curation platforms, including the EU climate change mitigation portal[10]. It is also expected to facilitate exploitation and maintenance of selected decision support tools developed by other EU-funded climate change research projects in close cooperation with the Commission services.

Communication, dissemination and cross-fertilisation of research results will be an important component of the action and should include support to upscaling the efforts of individual projects under Destination 1. These activities are expected to account for the majority of the action's budget and should be accordingly substantiated in the proposal. Activities should go beyond standard (passive) practices and could include, for example, Massive Online Open Courses, videos, mobile apps, festivals, citizen debates and other forms of active outreach, where possible and appropriate building on existing tools and materials developed by EU-funded projects. They should address a broad range of audiences, including policy makers, business and civil society with particular emphasis on young people, and taking into account each audience's specific needs, with a view to increase awareness about the state of climate science, build support for climate action and trigger broader societal transformation. National, regional and local level initiatives should be an important component of the outreach.

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[9] It includes relevant projects financed under the Call - Building a low-carbon, climate resilient future: climate action in support of the Paris Agreement, notably under focus areas: Decarbonisation, Climate adaptation, impacts and services; the Cryosphere and the Knowledge gaps. The final list is to be agreed with the European Commission.

[10] https://climatechangemitigation.eu

Innovative approaches, such as, for example, UNEP's "Earth School"[11], podcasts or TED talks[12], fully leveraging digital and social media opportunities, are strongly encouraged. The action should mobilise and promote direct interaction between the scientific community and civil society/practitioners. In addition, it should also support efforts to counter misconceptions, fake news and conspiracy theories regarding climate change.

Finally, the action is also expected to investigate options to best contribute to the objectives and activities of the European Climate Pact[13].

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, notably as regards exploration of the most effective techniques of communication, dissemination and engagement, in order to produce meaningful and significant effects enhancing the societal impact of the related research activities.

b) Maximising the synergy of climate change research and innovation in Europe

This action will help strengthen the European Research Area by ensuring coordination, cooperation and synergies between research, innovation and technology policies and programmes in the area of climate change research, including mitigation and adaptation, at European, national and regional level.

Maximising the societal impact of climate change research in Europe requires coordination among programming European, national and regional initiatives. Climate services, mitigation and adaptation options pioneered in one area should be deployable in another. In basic climate science, collaboration is increasingly important in order to strengthen the robustness, certainty and spatial and temporal resolution of projections.

The action is expected to help prioritise investments in climate change R&I and to add value to current and future R&I occurring across the ERA by exploiting potential synergies in R&I planning and activities, and opportunities for partnerships or complementary activities. To achieve this objective, the action should facilitate dialogue and exchange of information among the relevant scientific communities and funding bodies at European, national and regional level. It should identify and systematically update research needs emerging from science, policy discussions and the society, and enable the inclusion of these priorities in national and regional research strategies and agendas to finance ongoing and future projects.

A science-policy and science-society dialogue should be established, when possible in coordination with similar initiatives organised by other projects or entities, to improve access to and communication and dissemination of excellent climate change research and innovation. Activities will enhance cooperation between climate research scientist, professionals and all relevant stakeholders (e.g. universities, business and other research and innovation actors), accelerate the transfer of knowledge to inform policy and climate actions in Europe, and translate results into the society and the economy.

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[11] https://www.unenvironment.org/explore-topics/education-environment/what-we-do/earth-school

[12] https://countdown.ted.com/

[13] In the context of the European Green Deal which sets ambitious goals towards achieving climate neutrality by 2050, the objective of the Climate Pact is to raise awareness on climate change, to engage citizens and communities in action for climate and environment and to build on and amplify existing initiatives in Europe.

Activities should identify good practices at European, national and regional level on communication, dissemination and exploitation of climate change research findings and projects results (e.g. the Horizon Results Booster) and facilitate their scaling up.

Coordination will be ensured with relevant European, national and regional initiatives (e.g. Joint Programming Initiatives, EIT Climate-KIC…).

The activities should build links with relevant EU programmes such as Copernicus, as well as build upon and link to global structures like the IPCC, the Global Carbon Project and the Global Convenant of Mayors.

Projects funded under this topic should plan for ensuring coordination between their activities.

C5-D1-CSR-06-2021: Enhanced integrated assessment in pursuit of global climate goals

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

Expected Outcomes:

Under the Paris Agreement, Parties to the UNFCCC have to pursue policies and measures to reduce their greenhouse gas emissions, including by preparing and implementing successive Nationally Determined Contributions (NDCs) towards the Agreement's objectives. By 2025, countries are expected to produce new NDCs covering the post-2030 period, informed during the 2022-23 period by the 6th Assessment Report of the IPCC and the Paris Agreement Global Stocktake.

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

- Provision of information for the preparation of climate policies and national planning for the post-2030 period, in light of the Paris Agreement goals and the need to reduce global net greenhouse emissions to zero by 2050.
- Enhanced international cooperation among the modelling community and other relevant stakeholders to expand the provision of robust in-country advice to decision-makers around the world.
- Enhanced mutual learning among the modelling, social science and policy communities to ensure coherence between different tools used to inform climate action, and consistency with the best available and open science.

Scope:

- Ensure that Integrated Assessment Models enable the assessment of Paris Agreement-compatible mitigation policies to which policymakers around the world have access.
- Deliver advice and insights that can inform climate action and sustainable development policy design, including biodiversity preservation, at global and national level, based on the best available science.

- Support comparability of model results e.g. between national and global scenarios, and between Integrated Assessment Models and other models used to inform climate action at different geographical scales.
- Identify milestones, drivers and barriers towards achieving climate neutrality in an economically, socially and environmentally responsible way, including where appropriate by examining implementation of previous or existing climate policies.
- Consider the role of major sectors including energy, transport, industry and land use, as well as the sequence of individual, social, economic, structural, and technological changes that could lead to climate neutrality.
- Support the use of model-based and data/driven analysis for climate-policy in the context of sustainable development and recovery from the economic and social impacts of the COVID-19 pandemic.
- Share best practices and build capacities to support the production of national scenarios and to inform domestic stakeholders during and after the lifespan of the action.

Reflecting the nature of climate change as a global challenge, actions should be able to provide insights at global level and of relevance to major emitters and countries from different regions, with different levels of economic development and in-country scientific and institutional capacity.

International cooperation is encouraged, in particular with one or more of the top ten emitters[14] and with non-high-income countries[15] requiring support for the design and implementation of current and future NDCs.

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.

C5-D1-CSR-07-2022: Improvement of Integrated Assessment Models in support of climate policies

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Legal and financial set-up of the Grant	The conditions are described in General Annex G.

[14] For a ranking, see e.g. here: http://www.globalcarbonatlas.org/en/CO2-emissions or https://www.wri.org/blog/2017/04/interactive-chart-explains-worlds-top-10-emitters-and-how-theyve-changed.
[15] As defined by the World Bank.

Agreements	if needed, add exceptions here: On request, full royalty free access (under confidentiality clause) for Union institutions, bodies, offices or agencies for developing, implementing and monitoring Union policies or programmes, to all the tools and instruments necessary to reproduce and validate research results generated by the action (including access to data and model code).

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

- Improved adequacy of Integrated Assessment Models (IAMs) to effectively contribute to international, European, national and regional climate policy processes that integrate biodiversity objectives, in support of the European Green Deal, the Paris Agreement, COVID-19 recovery and sustainability goals.
- Contributions to major international scientific assessments such as the reports of the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the International Resource Panel (IRP).
- Increased robustness, legitimacy, relevance, usability and transparency of IAMs leading to increased uptake and better awareness of their results across various end-user groups, developing, where possible, new business models for IAMs transparency (for example, open source and open code options).
- Enhanced coherence between climate action (mitigation, understanding of impacts, climate risks and adaptation) and other sustainability objectives based on more realistic representation of their interactions, including co-benefits and trade-offs.
- More active involvement of citizens in climate action based on better understanding and demonstration of how small scale actions (including but not limited to behavioural change) contribute to the achievement of large-scale climate policy objectives, and better understanding of which actions/policies are more effective.
- Ultimately, accelerated transition towards climate neutrality based on improved knowledge and better designed policies that are more integrated, greener, healthier and more inclusive.

Scope:

Actions should improve the state-of-the-art of IAMs by tackling their existing weaknesses and lack of/limited capabilities of the current generation of models in order to provide robust, credible and transparent evidence-base in support of design and evaluation of multiscale (global, European, national, regional) mitigation policies at various time horizons.

An important goal of this call is to address multiple challenges in a coherent and consistent manner using an integrated framework. To achieve this goal, it is not compulsory to incorporate all issues into a single IAM. Combinations of hard linking, soft linking and other ways of insuring a coherent approach between models and experts can be considered.

Actions should address developments and improvements, such as:

- Sectorial detail and (transformative/structural) changes across various sectors of the economy such as those resulting from increased circularity and digitalisation.

- Temporal resolution and technologicalical detail in order to better represent dynamic seasonal changes in demand and technological responsiveness in supply.
- Spatial resolution with outputs suitable for national/regional level analysis.
- Behavioural and lifestyle changes (and their effects on production and consumption patterns).
- Distributional and equity effects of climate policies.
- Interactions with the relevant sustainable development goals (such as co-benefits due to avoided impacts and trade-offs in areas such as health, biodiversity, food security etc.).
- Climate change impacts, including the extent to which they can be avoided through mitigation action, synergies and trade-offs between climate mitigation and adaptation policies.
- Financial sector and investment needs, including information in support of investment risk-reduction strategies (such improved uncertainty analysis and probability distribution of results) to mobilise capital to finance the transition towards a climate-neutral economy.
- Uncertainties and risk-management strategies for supporting mitigation policies.

The above list is non-exhaustive and actions also may propose new avenues of research, while duly justifying their choice and keeping in mind the impact on IAMs' relevance and adequacy as a decision-support tool. Actions should also explore options for making models more capable of responding to external shocks such as the COVID-19 pandemic or similar. While addressing the improvements, actions should take into account the modelling requirements and learnings resulting from the COVID-19 crisis.

Actions should build on the knowledge base developed by previous initiatives and are encouraged to establish links with other relevant projects financed from this work programme (e.g. circular economy, climate adaptation modelling) and by Horizon 2020. In order to avoid duplication of efforts, proposals should clearly demonstrate how they will go beyond the modelling state of art.

Actions are encouraged to explore alternative approaches to the mainstream economic assumptions typically underlying the models (such as fully functioning markets and perfect information) and investigate the right balance between model complexity and usability; participatory approaches, such as citizen science, could be appropriate modes of research for this action.

In order to maximise the impact, active involvement of the end-users (policy makers, business, civil society) in the co-design of models and validation of the outputs should be considered. Applicants should investigate and apply communication tools and strategies for improved interaction with stakeholders and dissemination of model results, duly accounting for the needs of non-technical audiences. They should also explore ways for bridging the gap between modelling theory and practical applications, including in support of behavioural change and societal transformation.

It is recommended to include capacity-building efforts to lower the entrance barriers to the established IAM community by involving research teams in EU Member States and associated countries that are less advanced in terms of modelling capabilities. Applicants should further develop the thinking around the best ways to apply modelling insights to policies, including by building on the learnings from the COVID-19 pandemic.

Actions are expected to substantially contribute to development and promotion of the highest standards of model transparency and openness, well beyond documentation and extending to aspects such as assumptions, architecture, code, data and outputs. In this respect, full openness of any new modules, models or tools developed from scratch or substantially improved with the use of EU funding (understood as extending to model code, architecture, data and outputs) is expected and any deviations from this should be duly substantiated.

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.

C5-D1-CSR-08-2022: Carbon Dioxide Removal approaches

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 6 and 7 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

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

- Support climate policies through an enhanced understanding of existing and emerging carbon dioxide removal options in terms of their technical readiness, key requirements (land and other resource needs, geographical and geological constraints, primary energy needs, etc.), short- and long-term sequestration potential, permanence, impacts (environmental, social, health, resource depletion, etc.) including potential co-benefits.
- Support climate models and integrated assessment models through an improved parametrisation of these technologies and solutions, allowing their better integration into pathways and strategies and broadening the carbon dioxide removal technology options that can be numerically modelled.
- A harmonised, comprehensive and transparent methodology for the characterisation and comparison of such technologies and the barriers to their deployment, which can facilitate public discourse on their role and impacts.
- Gain better insight into the extended, system-level impacts of these technologies by considering ripple effects (e.g. extended impacts, land benefits foregone, opportunity costs, and rebound effects).
- Develop abatement cost estimates in function of time profile as well as factors like scale of deployment, key input factors (e.g., land/sea space, energy, reservoirs).
- Exploration and demonstration of business/ policy/ MRV frameworks for CDR uptake at scale, ranging from plant level to incorporation of CDR in international MRV and accounting (for example in the case of bioenergy trade).

Scope:

Projects under this topic should identify an extended range of nature-based and technical CDR methods, analyse and characterise them in a consistent and transparent assessment framework. In this way, projects should:

- Deliver realistic estimates of each approach's potential scale, cost, and effectiveness: on the basis of factors such as technical readiness, key land and other resource needs, geographical and geological constraints, primary energy needs (and associated impacts, including emissions), short- and long-term sequestration potential (including risk of non-permanence), key impacts (environmental, social, health, resource depletion, etc.) and risks.
- Allow the better parametrisation of integrated assessment models with respect to removals as well a better design of forward-looking policies. Develop abatement cost estimates in function of time profile as well variables like scale of deployment and key input factors.
- Explore efficient incentive and governance frameworks to facilitate CDR uptake at scale, including social acceptance, ethical and regulatory considerations, as well as identifying major issues and options for establishing MRV and accounting systems associated with CDR in general and specific technologies where applicable.

Analysis under this action should be based on practical experiences (in particular with a range of land-based projects), existing pilot and experimental projects, technical and theoretical analysis and review, including system-level impacts by considering ripple effects through consequential analysis, including land benefits foregone, opportunity costs and rebound effects, key barriers to deployment and governance challenges.

Interactions with CCUS call under Destination 3 and C5-D2-BT-01-2021: Emerging technologies for a climate neutral Europe under Breakthrough Technologies are encouraged.

Projects investigating the use of CDR technologies for enhanced oil recovery are not eligible.

Where appropriate, interaction with the topics related to climate-ecosystem interaction (C5-D1-CSR-15-2021, C5-D1-CSR-16-2021 and C5-D1-CSR-17-2022) as well as marine topics (Cluser 6) is encouraged in order to foster integrative and system approaches including different scientific communities and disciplines, as well as different sectors of the society.

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.

C5-D1-CSR-09-2022: Socio-economic risks of climate change in Europe

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

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

- A comprehensive socio-economic evaluation of future climate change impacts across sectors, countries/regions, timescales and climate as well as socioeconomic scenarios with improved sectoral, cross-sectoral and spatial resolution of impact projections.
- Improved climate change related decision support based on better understanding (and quantification) of the socio-economic risks (and opportunities), associated with climate change impact, for both sudden onset extreme events and slow onset processes.
- Better evidence for ambitious climate policy response, both in terms of mitigation and adaptation measures, based on a better understanding of socio-economic risks in the absence of adequate mitigation and adaptation efforts (or when limits to adaptation are reached), leading to a more secure and more certain socio-economic future.
- Actionable insights based on data at the appropriate level of geographical scale and spatial resolution for decision-makers in public and private sectors, including national and regional level estimations, leading to enhanced adaptation efforts and to a more resilient Europe.
- Better integration of climate change risks in public and private sectors' investment decisions, including cost-efficiency - from property, through infrastructure up to regional and national supply chains - leading to increased long-term resilience.
- Enhanced coordination with European Commission's Joint Research Center on research concerning climate impacts and adaptation modelling in support to the Commission services.
- Provision of authoritative knowledge to inform the activities of the Horizon Europe Mission on Adaptation to climate change including societal transformation.

Scope:

Actions should improve the understanding of the nature and extent of physical risks from a changing climate and their integrated socio-economic implications in Europe in 2030, 2050 and 2100 timeframes. The analysis should evaluate the costs of inaction / "business as usual" by extrapolating current policies with different social and climatological scenarios. It should seek to capture the range of possible socio-economic climate-related risks including both those most likely to occur as well as those associated with low-probability high-impact climate events with potentially catastrophic outcomes. Indirect impacts should be part of the analysis as well as the impacts in the rest of the world with relevant spill over effects in the EU should also be considered.

A comparison with scenarios with lower degrees of warming (ambitious mitigation measures) should be included as well as the analysis of the costs and benefits of ambitious adaptation measures. Research should also improve the understanding of climate-related risks that are unlikely to be avoided through mitigation and/or adaptation and require urgent/specific response. The work could encompass improvements in adaptation modelling, in particular in impact areas with the highest potential damages. Actions should also take into account the impact of radical transformations envisaged in the context of the post-COVID recovery.

The impacts of climate risks should be assessed and monetised across various economic sectors aiming at an expansion of the existing impact categories and combining them into a coherent framework. Cross-sectorial impacts taking into account the interactions between various sectors should also be addressed. This research should equally encompass impact categories that cannot be directly monetised, but with either economy-wide implications or of critical importance for future human well-being, such as health (including the spread of infectious diseases), social justice and biodiversity/ecosystems. The development of appropriate tools and methodologies that are able to address these kinds of non-market based impacts is part of the scope. In addition, actions should aim at accounting for the various sources of uncertainty in a systematic way.

A national and as much as possible regional resolution should be aimed at in order to account for heterogeneity in terms of hazards, exposure, vulnerability (including adaptive capacities) and ability to manage risks across countries and regions. Distributional and further equity considerations associated with climate change impacts should also be investigated in order to inform the formulation of just mitigation and adaptation strategies. Development and testing of rapid analysis and assessment techniques using open data, tools and methodologies as well as work on an economy-wide damage function relating GDP losses or other metrics of public welfare and human wellbeing with temperature increase, could be part of the research, too.

Actions should identify and formulate recommendations for measures that should be implemented by various stakeholders groups to minimise the climate risks across Europe as well as the needs for future research. They should explore effective ways for bridging the gap between science, policy and practice. The findings will inform the Mission on Adaptation to climate change including societal transformation. The needs of the private sector in order to prepare for and adapt to climate change impacts should be an integral part of the work and could include development of approaches for better integration of climate risks into financing principles of the investment community.

This topic calls for a truly interdisciplinary approach combining a wide range of disciplines including economics, climate science, bio-geophysical modelling, data engineering, risk analysis, political and behavioural science etc. as well as for an active involvement of and co-creation with people and communities at risk. As much as possible, it should integrate the results of the existing studies and evidence-base, including from previously funded projects such as COACCH and other projects from call SC5-06-2016-2017[16]. To guarantee legitimacy, full openness of new modules, models and tools developed or substantially improved with the use of EU funding (understood as code, data and outputs) is expected.

Synergies with topic C5-D1-CSR-10-2021: Better understanding of the interactions between climate change impacts, mitigation and adaptation options, as well as with relevant topics in Cluster 3: Civil security for Society – Destination Area DRS02 on Support to improved disaster risk management and governance, should be explored and established. In addition, coordination with existing relevant initiatives on climate impacts and adaptation modelling should also be sought, in particular in the context of the PESETA assessment[17].

The Joint Research Centre (JRC) may participate as member of the consortium but is not eligible for funding.

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

[16] A list of other relevant projects can be found here: https://cordis.europa.eu/project/id/776479
[17] https://ec.europa.eu/jrc/en/peseta-iv

meaningful and significant effects enhancing the societal impact of the related research activities.

<u>Adaptation and climate services</u>

C5-D1-CSR-10-2021: Better understanding of the interactions between climate change impacts and risks, mitigation and adaptation options

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 6 and 7 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Legal and financial set-up of the Grant Agreements	The conditions are described in General Annex G. if needed, add exceptions here: • Open access to any new modules, models or tools developed from scratch or substantially improved with the use of EU funding (understood as extending to model code, architecture and data); • On request, full royalty free access (under confidentiality clause) for European Union Institutions, bodies, offices or agencies for developing, implementing and monitoring EU policies or programmes, to all the tools and instruments necessary to reproduce and validate research results generated by the action (this means access to data and model code).

<u>Expected Outcomes</u>: Project results are expected to contribute to some of the following expected outcomes:

- Enhanced understanding, supported by quantitative and qualitative analysis, of the interaction, complementarity and trade-offs between adaptation and mitigation measures and policies helping to overcome the silo approach within and between them and leading to more effective climate action policies.
- Better knowledge about the impacts of climate change and their interaction with mitigation pathways, including their feasibility across various scenarios of global warming.
- Enhanced legitimacy and robustness of integrated assessment frameworks based on more realistic representation of climate processes and their impacts.
- Contribution to enhanced collaboration among Working Groups 1, 2, and 3 of the Intergovernmental Panel on Climate Change.
- Support and interact with the activities of Horizon Europe Mission “Adaptation to climate change including societal transformation”.

<u>Scope</u>:

Actions should deliver progress in integrating the analysis of the impacts of climate change, mitigation pathways and adaptation strategies into a single framework to help understand and quantify their numerous interactions.

Progress is needed to better reflect the economic damages and reduced well-being due to climate change in mitigation pathway analysis. Actions should integrate state of the art climate science stemming from Earth System Models, reduced Complexity Models and similar into a common integrated assessment framework. This should include climate change impacts, biodiversity and ecological considerations, Earth system feedbacks and extreme events, and their interaction with mitigation pathways.

Actions should also improve the general understanding of the synergies, conflicts and trade-offs between mitigation and adaptation strategies. For example, many adaptation actions that need to be deployed at a large scale in the short to medium term (in parallel to ambitious mitigation efforts) can have negative impact in terms of emissions. This includes flood and coastal (hard) protection, irrigation and desalination measures as well as increased demand for cooling/air conditioning that are typically highly energy intensive and may put additional stress on energy systems. Another example of an interaction between adaptation and mitigation strategies is the shift towards regenerative and organic agriculture that provides adaptation benefits, but may require expansion of food production areas to compensate for lower productivity with the consequence of more deforestation. Any such potential conflicts and interdependencies should be investigated, taking into account cross-sectorial cascading effects and temporal differences.

Actions should then formulate a set of technical and policy recommendations, including sector-specific ones, targeting both public and private stakeholders, to reduce the tensions between mitigation and adaptation strategies. Given that the interactions between mitigation and adaptation often occur at regional and local scale, research should also aim at finding solutions to reconcile the different scales at which mitigation and adaptations strategies are implemented, including improving the territorial resolution of relevant tools. In addition, actions should evaluate the impact on the costs of mitigation and adaptation strategies in the EU when they are treated in an integrated manner. In order to achieve the above-mentioned objectives actions may work on improvements in the modelling of adaptation, particularly in the sectors where adaptation interacts with mitigation (such as energy and agriculture).

Actions should explore effective ways for bridging the gap between modelling theory and practical applications, including through active involvement of and co-creation with stakeholders and end-users from various relevant fields, including through case studies in order to test and replicate the results. This should include outreach activities to general public to better explain the trade-offs and interactions between mitigation and adaptation strategies and measures.

Synergies with relevant projects funded under this Work Programme as well those originating from Horizon 2020 should be explored and established during the course of the project. In particular, projects resulting from the topic C5-D1-CSR-09-2022: Socio-economic risks of climate change in Europe and from Cluster 3 on Disaster Resilient Societies should be foreseen.

When dealing with models, actions should promote the highest standards of transparency and openness, going well beyond documentation and extending to aspects such as assumptions, architecture, code and data that is managed in compliance with the FAIR principles18.

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

Projects funded under this topic should ensure the coordination of their activities.

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.

C5-D1-CSR-11-2021: Supporting and standardising climate services

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

Expected Outcomes:

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

- Support to the implementation of the EU Adaptation Strategy and the Mission on adaptation to climate change, including societal transformation e.g. by providing standardised tools for climate proofing and increasing resilience.
- Improved relevance of data, information and knowledge on climate change impacts and adaptation, as well as mitigation for users both in the private and public sectors.
- Enhanced value of climate services through standards and quality assurance procedures and communication.
- The generation of trust across supply and demand of knowledge and services, supporting the development of a market for climate services and the European climate service sector.
- Enhanced quality, impact, equity and performance of European climate services.
- Enhanced data and analytical tools for climate impacts, risks (including extremes, longer trends, and the combination of trends and extremes) and transition risks, as well as actionable knowledge for the formulation of recommendations, identification and appraisal of adaptation options addressing the needs of all stakeholders.
- Enhanced coordination and visibility of climate services activities.

Scope:

This topic is intended to improve the delivery of quality control and standards (including open and licensed) for climate services and to guarantee suitability, quality, and performance of digital solutions to manage climate risks and enhance adaptive capacities.

The scope of activities under this topic should cover the following aspects:

- Uncertainty analysis and quality control with supportive case studies at various levels (national to European and global), and delivery domains (public and private).
- Preparation of metadata guidelines to document in a comparative and transparent manner climate service data sources and processing methodologies, as well as

decision-making based on these services, and support FAIR[19] data management practices.

- Development of good practices, guidance, and standardization of climate information and verification methods for long-term forecast products.
- Definition of verification and certification methods to enhance quality and usability of climate services, including methods for the evaluation of their effectiveness.
- Coordination and promotion of European climate service activities, encouraging open exchange of knowledge, expertise and data and providing a science-user communication platform and improving synergies between regional, national, EU and international activities.
- Development of appropriate business models and knowledge brokerage activities to support scale-up and replication of climate services.
- Organisation of the European Climate Change Adaptation (ECCA) Conferences and contribution to other international conferences on climate change adaptation.

Actions should develop interdisciplinary and transdisciplinary activities. Regular enaggement with stakeholders should be foreseen to consider applications in case studies, and to test, benefit and allow replication and upscaling of the results.

These standards and schemes will also require supportive governance and other measures, such as training and capacity building, to promote and sustain their use and continued development. This includes the development of common terminology between user, provider, and purveyor communities.

Synergies should be explored with relevant activities under other Clusters, in particular clusters 3 and 4 and standardization efforts internationally and in Europe (e.g. the Climate Services partnership, the European Open Science Cloud (EOSC), Digital Europe Programme and the Copernicus Programme, amongst others). The action should build on the achievements of the H2020 ClimatEurope project and the ERA4CS.

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.

C5-D1-CSR-12-2022: Supporting the formulation of adaptation strategies through improved climate predictions in Europe and beyond

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 9 and 11 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

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

Type of action	Research and Innovation Action

Expected Outcomes:

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

- Support to the implementation of the new EU adaptation strategy and the Mission on adaptation to climate change, including societal transformation, through better access to improved knowledge about climate impacts and fit-for-purpose data on individual and collective climate risks for all levels of government and stakeholders.
- Reduced vulnerability to climate change impacts based on decadal predictions which are a key source of information for better planning of adaptation options.
- Improved assessment of risks for people and systems exposed to extreme weather and climate events.
- Enhanced scientific collaboration and exploitation of synergies across the EU and associated countries for the provision of climate information to stakeholders engaged with the implementation of the EU adaptation strategy.
- Enhanced European cooperation and leadership in climate sciences e.g. in the frame of the Euro-CORDEX initiative, a part of WCRP's Coordinated Regional Climate Downscaling Experiment project (CORDEX).

Scope:

Proposals should aim at improving seasonal to decadal prediction to boost their quality at regional to local scale in particular for Europe and for variables of high societal relevance. Actions will enable progress in closing the gap between current skill and potential predictability estimates, as well as better aligning with immediate adaptation needs of end-users and making those predictions actionable. Ultimately, methodologies need to be developed to merge simulations from long-term weather forecast to climate predictions and projections, resulting in seamless climate information from sub-seasonal to seasonal and decadal predictions for the next 30 years.

Proposals should also improve assessments of risk through extreme climate-related events on a range of temporal and spatial scales, as well as early detection of tipping points. Tackle uncertainties regarding regional patterns and magnitude of changes and improve understanding of how existing model biases affect the representation of extremes regarding the intensity and frequency of hazards, including the co-variability of different risk factors, and ultimately reducing the biases.

Better exploiting climate variables can enhance consistency with impact models and avoid potential mismatches, leading to better understanding of interactions between climate system and other natural and socio-economic systems (e.g. insurance practices) as well as feedbacks related to land use and cover, urban dynamics, air quality, etc., which are very relevant for model simulations at regional scale. Actions should explore novel ways of coupling existing impact models with climate models to provide quality forecast at the local scale, focussing for example on cities. Actions are encourage to develop guidance on selection or aggregation of model data for local impact assessments, with clear justification of the procedures, allowing transformation of uncertainty into a manageable package of information.

Coordination with the Destination Earth initiative can be proposed to ensure the timely development of "climate replicas" building on the new state-of-the-art IT infrastructure, including access to EU high performance computing resources and an operational platform to upload and integrate the models and data developed in the course of the projects.

Participants should also ensure synergies with relevant projects and initiatives (e.g. Digital Twin of the Ocean under the EU Greean Deal call and the Digital Europe Programme).

Model development should be properly connected with major programmes in the domain of Earth Observation such as the Copernicus Programme and the ESA science satellite missions in Europe, and the GEO initiative at global level.

Actions should ensure the dissemination of project results to policy-makers and stakeholders to support long-term planning, as well as the sharing of knowledge and experience between EU and third countries on climate change impact and adaptation option modelling and assessment.

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.

Social science to tackle climate change

C5-D1-CSR-13-2021: Improved economic methods for decision-making on climate and environmental policies

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

Expected Outcomes:

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

- Enhanced operational capacities of the methods of economic analysis, leading to their increased usage in the preparation of decision-making on climate and environmental policies. This includes, but is not limited to, improved cost-benefit, multi-criteria and cost-effectiveness analysis.
- Practical recommendations and conceptual guidelines for improved, methodologically transparent economic approaches and practices for public policy design and evaluation in the domain of climate and environment.
- Proposals on ways to produce a better reflection of the specificities and risks of environmental challenges in public policy and promoting precautionary responses.
- Enhanced efficiency, effectiveness and legitimacy of European regulatory and policy decisions by providing decision-makers, stakeholders and the public with more realistic ability to systematically assess the options and their consequences.
- Improved capacity for decision making under the conditions of (extreme) uncertainty.
- Factual evidence and insights for the design and evaluation of the implementation of major European policies such as in the domain of the European Green Deal, New Generation Europe, national recovery plans, and other relevant policies.

Scope:

Actions should focus on the improvement of methodologies, practices and techniques for conducting economic appraisal of environmental policies, taking into account the progress in relevant sciences and in the understanding of the limitations of the methodologies and tools used so far, notably in impact studies. The key environmental policies of interest under this topic are those addressing climate change and biodiversity loss and actions should foster integrated approaches for addressing these interdependent challenges. Innovative and out-of-the-box approaches are encouraged.

Actions are expected to investigate limitations of mainstream economic theory and models used for environmental policy assessment, including the evaluation of appropriateness of cost-benefit and cost-effectiveness analyses. They should also consider alternative approaches and theories that can be applied to assess environmental policies. Issues such as, for example, measurement of environmental/climate damages and the treatment of uncertainty, including overreliance on average and most likely outcomes as well as the non-linear features of climate-related risks are expected to be addressed. Other aspects that could be explored include short-termism, treatment of unpriced values, irreversibility, discounting, inclusiveness and socio-economic inequalities, and broader ethical issues such asintergenerational fairness.

The work should encompass in-depth ex-post evaluation of the actual performance of selected climate and environmental policies at European (e.g. the impact assessments underlying key legislative proposals[20]), national or regional level in order to identify their strengths and weaknesses and propose possible improvements in the underpinning methodologies for ex-ante assessments. Alternative approaches derived from the measurement of actual, realized costs and benefits of a representative sample of cases can also be considered.

Actions should also examine the performance of different types of regulatory strategies such as a comparison of market-based vs traditional (command and control) regulation, a comparison between different types of market-based approaches (taxes, emissions trading, green certificates, subsidies, etc.), evaluation of the performance of information-based mechanisms (such as labelling) for purposes of environmental policy-making. The analysis should take into account public acceptance dimension. The consortia are also encouraged to explore innovative policy interventions (such as incentives) that could be applied to encourage the adoption of more sustainbale technologies and behaviours.

Applicants should take into account not only the advances in economic thinking, but also the evolution in behavioural insights, study of public and political acceptance, as well as progress in other relevant fields such as sociology, natural and political sciences, humanities, public health and disaster risk reduction, as well as key trends that have influenced the evolution of the European environmental policy-making over the past decades. Lessons from the COVID-19 crisis should also be analysed. Participation of and co-creation with relevant stakeholders and key actors should be part of the action, including in-depth contribution from social sciences and humanities to advance the understanding of the dynamics and the factors impacting the policy and political decision-making processes.

Finally, actions should formulate and implement strong dissemination plan towards the key actors in relevant decision-making processes with an aim to testing the proposed methods in

[20] For European Commission's impact assessments please refer to https://ec.europa.eu/smart-regulation/impact/ia_carried_out/cia_2016_en.htm (Note: initiatives included in this data base may not be exhaustive and applicants are free to choose other case studies).

real conditions and the educational institutions in order to facilitate broad cross-fertilisation of the insights created.

In response to this topic actions are expected to address the broader framework and methodologies for economic analysis of environmental policies and thus go well beyond the economic aspects of Integrated Assessment Models.

Synergies with other topics, in particular from Cluster 6, should be explored and established as relevant.

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.

C5-D1-CSR-14-2022: Social science for land-use strategies in the context of climate change and biodiversity challenges

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 6 and 7 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

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

- A characterisation of future expected land use patterns consistent with long-term objectives (especially on climate, biodiversity and renewable energy) and its comparison with the current situation and trends.
- A comprehensive understanding of the key motivations and drivers (economic, regulatory, legal, cultural, environmental, etc.) behind land-use related decisions in Europe at levels ranging from land owners to public authorities at local, regional and national level, including their relative importance.
- A better understanding of the awareness of key actors (land owners, managers, local authorities, regulatory agencies) about climate change and biodiversity challenges and their willingness to contribute addressing them, including the adoption of new or different practices consistent with long-term expectations.
- Support to climate (mitigation, adaptation) and biodiversity policy design and implementation through economic and behavioural insights allowing the efficient targeting of incentives and engagement of stakeholders in a cost-effective manner, taking into account telecoupling (displacement effects through changes in imports and exports).

<u>Scope:</u>

Actions should aim to gain a realistic understanding of the factors behind land-use decisions and how they can be best oriented towards the efficient and socially responsible pursuit of multiple policy objectives on various scales (from the individual field/farm to region to national to continental scale). They should develop a toolbox of instruments and approaches deployable at different levels consistent with long-term goals and strategies considering, inter alia:

- The need for land to provide net sequestration and biomass flows consistent with the demands of various mitigation pathways, on different timescales.
- The continued need for land to provide food, feed and raw materials under increasing climate change and other pressures and needs (e.g., water availability, climate change resilience).
- The potential for demand-side measures that can contribute to long-term objectives (such as sustainable and healthy dietary change) and how they can be deployed.
- The crucial need for halting and, if possible, reversing biodiversity loss in Europe and globally.
- The socioeconomic dynamics, behavioural patterns and inertia related to land ownership, management and policies.
- The considerable diversity of land use patterns, approaches and biogeographic conditions in the EU, including land-related resources such as water.
- The need to make the instruments and approaches, including collective learning and negotiation processes at local and landscape scale, widely and practically available to the key actors, to enable sustainable change.
- The need to avoid rebound (detrimental displacement effects).

Actions should focus on one or more of the following issues:

a) Development of realistic scenarios and workable models for optimising the contribution of land to climate change mitigation, adaptation and biodiversity objectives, where possible integrating with Integrated Assessment Models (IAMs), consistent with expectations while reducing conflicts, exploiting synergies and managing risks (agroforestry can be one example of a system that allows higher productivity, more resilience and more biodiversity at the same time).

b) Economic and behavioural insights into land use related decisions, barriers to change, efficient design of incentives. This should explore the relative merits of instruments (regulatory, market-based, education, soft policy).

c) Explore a range of delivery mechanisms that could best incentivise the upscaling of the required changes under real-life situations in multiple settings (countries, biogeographical regions).

d) Develop workable models for effective and efficient monitoring and incentivising public goods benefits (such as emissions reductions, biodiversity protection and water services).

e) Contribute to the better quantification of land-related greenhouse gas flux trajectories for integrated assessment models on relevant scales (including displacement effects).

Participation of and co-creation with relevant societal stakeholders should be part of the action, including interdisciplinary and transdisciplinary research and the contribution from social sciences and other relevant disciplines.

Synergies should be ensured with topics related to land-use, biodiversity and ecosystems in Cluster 5 and in other Clusters, with the implementation of the Mission on Adaptation to climate change including societal transformation, as well as with other relevant actions, programmes and initiatives[21].

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

C5-D1-CSR-15-2021: Restoration of natural wetlands, peatlands and floodplains as a strategy for fast mitigation benefits; pathways, trade-offs and co-benefits

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 6 and 7 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

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

- Support the EU Nature Restoration Plan of the EU Biodiversity Strategy for 2030 2030.
- Improved assessment of the added value of wetland, peatland and floodplain restoration approaches and monitor their benefits and trade-offs in terms of greenhouse gas (GHG) emissions and removals, climate change adaptation and disaster risk reduction, a wide range of ecosystem services and biodiversity.
- Improve the knowledge base on the status of European wetlands beyond the current state of the art on extent, location, condition, type of management and pressures (including climate change), as well as restoration potential to understand their capacity as carbon sinks or GHG sources to support climate mitigation and adaptation plans/solutions.
- Introduction of the quantified greenhouse gas abatement potential of wetland restoration in models and scenarios, for climate and biodiversity.
- Analyse the degree to which these approaches related to wetlands are affected by different scenarios of climate change (i.e. effectivity under global warming of 2°C and higher).
- Support the implementation of the Land Use, Land Use Change and Forestry (LULUCF) Regulation with respect to the inclusion of wetland restoration activities by developing robust and transparent methodologies, data provision and analysis.

[21] E.g. UN Decade on Ecosystem Restoration.

- Contribute to the evidence on ecosystem services provided by restored wetlands and their long-term management as an investment with significant net societal benefits.
- Contribute to scientific assessments such as the IPCC, IPBES and International Resource Panel reports.

Scope:

Projects are expected to assess the current extent and state of European wetlands, their current and potential GHG profile (with or without protection/restoration measures) and their medium to long-term mitigation capacity through restoration or other measures. As a minimum, the assessment should take into account key greenhouse gases (CO_2, CH_4 and N_2O), the carbon value of services (such as production) in the baseline (e.g., food production) and restoration scenarios (e.g., paludiculture or non-productive uses, agritourism...) and estimate the abatement cost for different policy-relevant time periods. Assessments should therefore look at assessing any trade-offs of restoring wetlands primarily for climate and biodiversity benefits with the delivery of their wide range of other services, and on methods to avoid, and if not possible, to mitigate them.

Projects are expected to develop or identify workable tools and approaches for the sound estimation of GHG performance as well as impacts on biodiversity and a wide range of ecosystem services. The GHG emission during restoration (e.g. due to disturbance of soils, dredging of sediments, methane from rewetting) must be considered, including trade-offs and benefits of passive restoration and following succession of water bodies. The evidence collected may contribute to the related policies, like LULUCF, and the implementation of the Biodiversity Strategy commitments.

Projects are expected to go beyond the state-of-the-art of restoration and management techniques and knowledge and provide recommendations about the scaling up of the solutions. In particular, to the projects must capitalise on the evidence provided by LIFE, Horizon 2020 and ERDF projects addressing wetland, floodplains and peatland restoration and protection.

Actions should envisage clustering activities with other relevant selected for cross-projects co-operation, consultations and joint activities on cross-cutting 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.

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.

C5-D1-CSR-16-2021: The contribution of forest management to climate action: pathways, trade-offs and co-benefits

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 5 to 7 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Type of action	Research and Innovation Action

Expected Outcomes:

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

- A comprehensive assessment of the climate mitigation potential of EU forests and forest-based sector through modelling of different policy pathways, taking into account climate change related risks, physiological and biogeochemical responses to environmental change and management practices, adaptation needs, biodiversity goals, and the provision of other ecosystem services. The effects analysed have to include changes in carbon sequestration, forest health, productivity, substitution and biophysical factors, including the causes and time dynamics of these changes. The assessment of the potential and limits of forest-based products and biomass for energy in delivering climate benefits will inform public authorities on the most suitable approach to forest policy and forest bioeconomy.
- Development and improvement of robust and transparent methodologies for high-resolution monitoring and reporting of forest carbon pools and their interactions through a combination of in-situ data collection and remote sensing methods to be used to advance land use, land-use change and forestry (LULUCF) reporting under the UNFCCC and compliance under EU legislation. Methods developed under this action will additionally feed into the development of the Forest Information System for Europe (FISE).

Scope:

Proposals under this topic should develop a comprehensive assessment of different pathways of the EU forest GHG balance and other climate objectives incorporating:

- Biodiversity goals consistent with the EGD objectives and Biodiversity Strategy 2030 goals connected to the use non-native tree species, intensive thinning, transition between intensive and close-to-nature silviculture, and strict protection of forests.
- Uncertainties related to climate change and natural disturbances
- Adaptation needs of existing and future forests and (re)afforestation plans, including factors determining their adaptation potential.
- Mitigation potential of afforestation and other forest activities including their opportunity costs.
- GHG impact of forest bioeconomy, including substitution effect of forest-based products and energy against realistic counterfactuals and with appropriate time dynamics.
- Renewable energy targets and the needs of forest-based bioeconomy for sustainable domestically-sourced feedstock.
- Biophysical effects, including changes in air temperature and precipitation associated to changes in surface albedo, land-surface properties, emissions of biogenic volatile organic compounds, transpiration and heat flux.
- Assessment of trade-offs and synergies between climate-oriented forest management, and other objectives such as recreational and amenity values;

Having such models/assessment at their disposal and understanding their time dynamics, uncertainties and system boundaries, policy-makers will be better suited to incorporate forests in the design and evaluation of possible solutions and pathways for climate change mitigation and adaptation.

Monitoring and reporting on changes to forest carbon stocks is essential for policymakers (both national and EU) in order to be informed of trends in the forest sink evolution and to develop annual approximated greenhouse gas inventories. Actions should support the use of higher tier (and higher accuracy) methodologies and geographically explicit land-use data in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[22] and its 2019 Refinement[23]. Especially needed are actions to fill existing gaps resulting from inventory bias towards the most economically relevant tree species and carbon pools.

Proposals under this topic should therefore aim to develop knowledge, tools, models, databases and country- and region-specific values available to Member States, where possible integrating with Integrated Assessment Models (IAMs) and climate models to improve monitoring and reporting of forest carbon pools. Remote sensing data sets can be helpful in estimating or verifying forest living biomass gains and losses, forest area changes, forest health status and in identifying carbon-rich old-growth forests or natural disturbances. Sample-based systems, on the other hand, should support mapping changes in other forest carbon pools such as soil organic carbon in mineral and organic soils, and dead organic matter. More robust estimation of fluxes among these forest carbon pools, which are often neglected in greenhouse gas inventories, will assist in estimating their importance as carbon reservoirs and the role that forest management can play in enhancing them, taking into account biodiversity needs and resilience. Considering biophysical effects will improve the understanding of trade-offs among climate objectives and their articulation with forest management practices.

Actions should envisage clustering activities with other relevant actions, initiatives and programmes, including Horizon 2020 Work Programmes and the LIFE Programme, COPERNICUS and relevant research infrastructures to promote synergies, integration and co-operation. They should make use and contribute to knowledge exchange and networking European platforms. The Joint Research Centre (JRC) may participate as a member of the consortium but is not eligible for funding. Cooperation and planning for further exploitation of actions results during and after the project end is strongly encouraged.

C5-D1-CSR-17-2022: Let nature help do the job: Rewilding landscapes for carbon sequestration, climate adaptation and biodiversity support

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 8 and 9 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

[22] https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html
[23] https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html

Type of action	Research and Innovation Action

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

- Contribution to IPBES and IPCC, to the achievement of objectives of reaching net zero carbon emissions, enhancing climate change adaptation, and to the EU Biodiversity Strategy.
- Support the implementation of the Horizon Europe Mission on Adaptation to climate change including societal transformation.
- Identify low cost/benefit ratio options to restore natural and semi-natural ecosystems for carbon sequestration and biodiversity conservation.
- Assess the value of restoring ecosystem for adaptation to and/or mitigation of climate change and identify potential rebound effects and trade-offs.
- Demonstrate the degree to which these approaches are affected by climate change itself and if they can still be effective under global warming of 2°C and higher.
- Demonstrate the potential contribution of EU abandoned land and protected areas systems for carbon sequestration, adaptation to and/or mitigation of climate change.
- Develop strategies to minimize the increasing risk of wildfires due to the changing climate.
- Provide operational methods for low cost, low human intervention options for ecosystems restoration optimising the contributions to climate and biodiversity objectives and managing trade-offs.
- Help generate data and methodologies for better integration of land-use management systems into IAMs and ESMs.
- Assess the perception and acceptability of citizens and stakeholders on rewilding and rewilding options and identify potential conflicts and trade-offs in governance and decision-making.

Scope:

The biodiversity crisis and the climate crisis are intrinsically linked and the contribution of Nature-based Solutions (NBS) to the global climate objectives is pivotal. A better understanding of how the use of ecosystems natural capacity, with minimal help from humans, can contribute to carbon sequestration and biodiversity conservation is urgently needed to make the use of NBS operational.

Actions should foster interdisciplinary research with a focus on the climate-biodiversity nexus, advancing our knowledge to further promote integrated approaches to better address these interdependent challenges.

Actions, taking stock of previous and ongoing experience, including associated uncertainty, should provide a robust assessment of the potential contribution that restoring ecosystems, including trophic chains restoration, with a “let nature do the job”, also called “rewilding”, approach can provide in terms of carbon sequestration and storage, climate change mitigation and adaptation and biodiversity conservation. “Rewilding” is meant here as passive management of ecological succession with the goal of restoring natural ecosystem processes and reducing human control of landscapes, although some intervention may be required in the early restoration stages.

Actions can address specific ecosystems and/or landscapes on land, freshwater, coastal and marine ecosystems while providing a clear contribution to define the potential use of the "rewilding" approach at regional, national and continental levels.

Actions should build on an updated and detailed picture of the status and trends of ecosystems change, (including, where applicable, land abandonment) in Europe to assess where, at which ecological conditions and at what scale the "rewilding" approach can significantly improve carbon sequestration together with habitats reinforcement and biodiversity conservation.

Actions should investigate how "rewilding" can be complemented with other approaches (for example active restoration and conservation, low intensity farming, forestry and pasture management, fishing), taking into account specific regional conditions, to increase carbon sequestration, improve biodiversity conservation and ensure provision of goods and ecosystem services.

Actions should provide scientific insights, tools, methodologies and innovative solutions to assist national governments, regions and communities in embedding the "rewilding" approach, as far as feasible, in their own plans to reach carbon neutrality. Actions should also advance the integration of land use options for carbon sequestration into IAMs and ESMs.

Actions should significantly advance knowledge on the role and relevance of restoring fully functional trophic chains, for instance through the conservation, management and reintroduction of apex predators, grazers and scavengers, in the "rewilding" process, with a special focus on the functioning of trophic cascades on landscape processes and the ability of ecosystems to act as carbon sinks. Challenges and barriers to this aim should be analysed and the involvement of Social Sciences and Humanities is recommended.

Actions should ensure appropriate interdisciplinarity to embed socio-economic aspects, including opportunities for economic development, existing barriers (ecological, social…) and potential synergies and drawbacks.

Actions should envisage clustering activities with other relevant actions, initiatives and programmes, including Horizon 2020 Work Programmes and the LIFE Programme to promote synergies, integration and co-operation. They should make use and contribute to knowledge exchange and networking European platforms (e.g. Climate-ADAPT, Network Nature, OPPLA, BiodivERsA). Cooperation and planning for further exploitation of actions results during and after the project end is strongly encouraged.

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.

Destination 2 – 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 (as set out in the legal base), such areas are batteries, hydrogen[24], communities and cities, early-stage breakthough 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. A more detailed descrition of the specific context of each area is provided below.

<u>Expected impacts at Destination-level and their link to expected impacts of the Strategic Plan</u>

Activities under this Destination should set out a credible pathway for contributing to the following **Destination-level expected impacts** (more detailed impacts for each thematic area are elaborated in the introductory text of the thematic area):

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.

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.

c) Facilitate 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.

d) **Nurture the development of emerging technologies** with high potential to enable zero-greenhouse gas and negative emissions in energy and transport;

These Destination-level impacts will directly support the **Strategic Plan's expected impact** of *"Clean and sustainable transition of the energy and transport sectors towards climate neutrality facilitated by innovative cross-cutting solutions"*.

A competitive and sustainable European battery value chain

Mobility and energy sectors face substantial and sustained environmental, societal, and political pressure to shift towards clean technologies without sacrificing job-creation and growth. Batteries will enable the rollout of zero-emission mobility and renewable energy

[24] Hydrogen is primarily addressed though the Institutional European Partnership 'Clean Hydrogen'.

storage, contributing to the European Green Deal and supporting the UN SDGs by creating a vibrant, responsible and sustainable market. Besides decarbonization, batteries also contribute to other UN SDGs directly and indirectlysuch as enabling ofdecentralized and off-grid energy solutions.

High performing batteries are an essential energy storage technology necessary for Europe to succeed in this transition. The introduction of such batteries can only be realised by delivering breakthrough innovation and disruptive inventions to push the boundaries of technological performance of battery materials and chemistries, increasing the effectiveness of manufacturing processes, ensuring smart integration in applications and interoperability with the rest of the smart energy system components at all levels, and guaranteeing reuse or recycling and sustainability of the whole battery value chain.

The strategic pathway therefore 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" aims to establish world-leadingsustainable and circular European battery value chain to drive transformation towards a carbon-neutral society. The Partnership's ambition is to prepare and equip Europe to commercialise the next-generation of battery technologies by 2030, which will accompany the large-scale deployment of zero-emission mobility and renewable energy storage. It will also cover longer term research on future battery technologies which are essential for ensuring the long-term competitiveness and global leadership of the European battery industry.

The main impacts to be generated by topics included in this work programme are:

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

b) Accelerated growth of innovative, competitive and sustainable battery manufacturing industry in Europe;

c) Increased overall sustainability and improved Life Cycle Assessment of each segment of the battery value chain, the latter, to be specifically developed in a joint topic with 2Zero partnership (C5-D5-BAT-ZERT-20-2021: LCA and design for sustainable circularity - holistic approach for zero-emission mobility solutions and the related battery value chain)

d) Developed and established innovative recycling network and technologies;

e) Accelerated roll out of electrified mobility through increased attractiveness for citizens and businesses, offering lower price, better performance and safety, reliable operation of e-vehicles;

f) Increased grid flexibility, increased share of renewables integration and facilitated self-consumption and participation in energy markets by citizens and businesses;

g) Increased exploitation and reliability of batteries though demonstration of innovative use cases of battery integration in stationary energy storage and vehicles/vessels/aircrafts (in collaboration with other partnerships);

h) Established the best-in-the-world innovative battery R&I ecosystem, developing strategic forward-looking orientations to ensure future skills development, knowledge and technological leadership for accelerated disruptive technology exploration and uptake.

The following topics are currently being considered for further development:

Raw materials processing technologies

C5-D2-BAT-01-2021: Sustainable processing, refining and recycling of raw materials

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between 6 and 7 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action.
Technology or societal readiness level	Activities are expected to achieve TRL 4-5

Expected outcomes:

Raw materials shall be competitively produced and refined in Europe in a sustainable way, including reduced environmental footprint, and improved social aspects and competitiveness.

Project results shall contribute to decreasing dependency of of the EU on imported battery chemicals and raw materials. As a result new business opportunities and jobs shall be created for the EU industry.

Projects shall coordinate with projects funded under *Cluster 4 RESILIENCE Green and Sustainable Materials topics.* Projects shall contribute to European Raw Materials Alliance objectives.

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

- European low-grade deposits and secondary material sources such as tailings as source of nickel, cobalt and lithium are taken into use, reducing the European dependency on important materials by increasing refining capacity to battery grade materials in EU. This requires innovative, cost-effective and safe extraction technologies.
- Battery grade intermediates such as lithium hydroxide and precursor materials are competitively produced and refined in Europe in a sustainable and socially acceptable way, improving the competitiveness and value of European battery and mobility industries.
- Reduced carbon emissions, increased energy efficiency, and more efficient resource use and yield, for example by increasing the capacity to re-process recycled lithium from spent batteries integrated in primary lithium processing
- New business opportunities and models for the EU industry (e.g. joint processing, centralised Lithium refinery) creating additional jobs from increased processing and refining capacity

Scope:

In order to secure a competitive battery industry in Europe, innovations in chemical and metallurgical production are required. The focus is at improved yield, better process control, flowsheet flexibility, improved product purity and quality, improved impurity removal, and improved recovery from secondary streams. These innovations are in some cases complementary unit processes to existing process flow sheets, while in others, such as European lithium or precursor production, completely new flowsheets. These advancements are expected to bring the European battery metal and chemical production to a global leadership. The activities shall cover one or several bullets:

- Solutions to a sustainable Lithium value chain, such as:
    - Novel sorting technologies, new comminution method and alternative energy sources to improve energy efficiency, CO2 emissions and reduce water use in lithium processing and refining.
    - Selective methods for lithium extraction from pegmatites and other Lithium bearing minerals and refining of lithium materials to battery grade chemicals or even to lithium metal. Improvement of stability of refined LiOH. Cross-connections to other relevant WP parts which cover raw mat. issues (eg. C4) will be established.
    - Specification of physical-chemical properties for Lithium deposits, to foresee how the mineral mix could be better processed.
- New refining processes to increase value and yield from European mines and sustainably sourced and imported (nickel and cobalt) raw materials, but also from process waste, side streams, recycled materials, mine tailings and other non-conventional sources.
- Improvements in performance and efficiency of existing (nickel and cobalt) refining processes in Europe, e.g. by implementing new methodologies to reduce carbon emissions, increasing energy and resource efficiency, raw material flexibility and substitution of fossil fuels.
    - Development of new recoverable reagents and processes and real-time composition analysis for battery metal leaching and extraction to reduce waste and improve material efficiency
    - New smelting and slag engineering technologies to address Ni and Co losses in smelting
- Development of continuous processes for precursor materials (pCAM) to replace the currently used batch processing, including:
    - Process control solutions for different cathode active material recipes
    - Complete process design concepts including filtration, gas supply, mixing ratios, flow control, fluidised process solutions, and process automation
    - Process optimisation to minimise and/or recover off-specification battery metals and compounds.
- Zero Liquid Discharge processing in battery chemical and precursor material processing, including energy cascading and waste valorisation
- New business models for co-processing and process integration

- Process modelling competence combined with environmental impact evaluation (incl. LCA) for individual primary processes, in collaboration with a project funded under C5-D5-BAT-ZERT-20-2021.

C5-D2-BAT-02-2022: Sustainable processing and refining of battery grade graphite

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 6-7

<u>Expected outcomes:</u>

For graphite, both natural and synthetic graphite production for the EV market take place almost exclusively in China. Although there is some existing mining of Natural graphite in Europe, scaling these sources for the active anode material needs within Europe will be very challenging as (i) extensive graphite exploration and mining would be needed, and (ii) almost all of the refining capacity is based in China. The main challenges in refining are low yield in the spheronisation and the use of large amounts of hydrofluoric acid in the refining step.

For synthetic graphite, by-products of oil distillation are used as the starting point, followed by calcining, milling, shaping and graphitisation. This process produces high quality anode graphite (enabling long lifetimes and fast charging) but is energy intensive and causes environmental emissions (CO_2, PAH). Opportunities to overcome all these problems exist already in Europe but need further development and investment to reach the required scale.

Project results are expected to contribute to all of the following expected outcomes on either natural or synthetic graphite production respectively:

- Decreased dependency of EU on imported battery grade graphite and decreased risk in European Battery supply chains
- Graphite (both natural and synthetic) competitively produced and refined in Europe in a sustainable and socially acceptable way improving the competitiveness of European batteries
- Reduced carbon and environmental emissions from the anode material supply chain
- Projects shall contribute to European Raw Materials Alliance objectives.

The Synthetic graphite projects are expected to focus additionally on:

- System prototype demonstration of battery grade anode graphite material with high energy density, long lifetime and quality enabling fast charging, produced with increased yield and lower environmental footprint.
- As a longer-term option, biocarbon alternatives to petroleum coke shall be developed to ensure long term sustainable supply

The Natural graphite projects are expected to focus additionally on:

- Advanced refining of Natural graphite to improve the yield of battery grade products and lower the environmental footprint

Scope:

- Enabling European graphite production – with vertical integration into the European battery production. Resource efficient sustainable production of both synthetic and natural graphite emphasising reduction of energy consumption, CO_2 emissions, chemical use and the optimisation of recovery yield and raw material consumption. Enhance versatility regarding products and usable primary/secondary raw materials.
- Development of solutions for combined use of natural and synthetic graphite

For natural graphite:

- Improving purification, milling, shaping and coating technologies that improve the performance characteristics of natural graphite.
- Improving the yield of spheronised products from natural graphite concentrate
- Development of a non-HF purification technology to produce battery-grade anode material from spheronised natural graphite.
- Developing improved coating technologies for natural graphite that will increase the performance characteristics of natural compared to synthetic.

For synthetic graphite:

- Improving graphitisation, calcining, milling, shaping and coating that improve the performance characteristics of synthetic graphite.
- The use of other available European carbon options like biobased anode carbon and by-products from anode material production as raw materials for synthetic graphite shall be developed.
- Development of new processes for synthetic graphite production from natural gas pyrolysis
- Reduction of process discharge and emissions in synthetic graphite production.

Advanced materials

C5-D2-BAT-03-2021: Advanced high-performance Generation 3b (high capacity / high voltage) Li-ion batteries supporting electro mobility and other applications

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between 6 and 8 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 6 and higher.

Expected outcomes:

Projects are expected to contribute to the following outcomes:

- Advanced Li-ion batteries delivering on cost, performance, safety, sustainability and recyclability, with clear prospects for cost-competitive large-scale manufacturing and uptake by the electromobility as well as other application sectors.
- Increase in energy density and hence on driving distance at reduced cost on pack level, inducing a broader buyer's acceptance
- Broader acceptance leading to a significantly broader market penetration, helping to reduce GHG emissions of the transport and industry sectors to support EU's efforts to become climate-neutral by 2050: demonstrated for recyclability.

Translating these outcomes into indicative KPIs to guide the R&I efforts, it is recommended to target the following for impact by 2025and beyond:

- Gravimetric, volume energy density at cell level of 350-400 Wh/kg, 750-1000 Wh/l respectively
- Power density at cell level of 700 W/kg, 1500+ W/L
- For high voltage application, operation at 4.7+ Volt
- 3000+ and 2000+ deep cycles for high capacity and high voltage applications respectively
- Cost at pack level < 100 euro/kWh

<u>Scope:</u>

The overarching R&I challenges lie in the development of advanced materials enabling higher energy / power density thanks to higher capacity (voltage range 4.3-4.5V) and/or operating at higher voltage (4.7+V). Focus is on adapting the cathode materials (high-nickel NMCs for capacity, spinels / Li-rich Mn NMCs for voltage), the anode materials (graphite-containing Si(Ox)), the electrolytes (stabilised formulations) … and their interplay.

- **For the higher capacity approach, focusing on maximising energy and power density should address topics such as**
  - high-capacity cathode materials operating in 4.3-4.5 Volt range while delivering on cycle life, protective coatings for safety improvements,
  - high-performance anodes with advanced graphite and silicon materials (increase Si content in Si/C anodes to achieve capacities ideally at 1000 mAh/g), - Other option is to, develop complete Si or other alloying anode solutions in nanostructured form
  - suitable inactive materials (binders, conductive carbons, current collectors, separators),
  - electrolytes stable in 4.3-4.5 Volt (new additives and/or solvent systems), advanced processing routes for the novel materials and advanced electrode and cell/module designs.
- **For the higher voltage approach, focusing on maximising energy and power density should address topics such as**
  - high-voltage stable electrolyte systems (new electrolytes and/or new formulations),

- high-voltage stable cathode active materials (e.g. HV spinels, Li-rich Mn NMCs, phosphates, disordered materials etc. with lowered content in critical and high price elements),
- tailoring and operando monitoring of the electrochemical interplay between the cathode active material and the electrolyte formation of stable SEI interfaces,
- advanced high performance anodes matching these high-voltage cathodes and electrolytes,
- structuring of the cathode and anode electrodes for among others their competition and electric conductivities.

C5-D2-BAT-04-2021: Advanced high-performance Generation 4a, 4b (solid-state) Li-ion batteries supporting electro mobility and other applications

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between 8 and 9 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5

Expected outcomes:

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

- Advanced Li-ion batteries delivering on cost, performance, safety, thermal stability, sustainability with clear prospects for cost-competitive large-scale manufacturing and uptake by electro mobility sector
- Increase in energy density and hence on driving distance at reduced costs on pack level, will positively affect the buyer's acceptance
- Broader acceptance will help to reduce GHG emissions of the transport sector and support EU's efforts to become climate-neutral by 2050

Translating these outcomes into indicative KPIs to guide the R&I efforts, it is recommended to target the following for impact by 2030 and beyond:

- Gravimetric energy density at cell level of 400+ Wh/kg volumetric energy density at cell level of 800+ Wh/l (Gen 4a) progressing to 1000+ Wh/l (Gen 4b).
- Cycle life in a 1000 – 3000 range and ability to operate at charging rate of 3-5C (for aviation up to 10C)
- Cost at pack level down to below 75 euro/kWh
- High-power variants for fast charging, airborne, heavy-duty, hybrid segments targeting >500W/kg and >700 W/l.

Scope:

The overarching R&I challenges lie in the development of solid-state electrolytes, cathode materials and anode materials enabling higher thermal and electrochemical stability while targeting higher energy / power densities, fast charging, cyclability and improved safety. These new materials should contribute in the control of thermal runaway at early stage, and create non-propagation designs. Developments should range from using conventional materials to using Li metal-based anode materials. Projects shall bealigned with ongoing H2020 projects on the subject, esp. from H2020-LC-BAT-2020 call and their publicly-available results.

- **For Generation 4a (solid state with conventional materials) projects shall cover all bullets:**
    - developing low direct current resistance active materials,
    - reducing thickness of the anode,
    - developing thin solid electrolyte with high ionic conductivity,
    - manufacturing new solid electrolyte interlayers,
    - improving interface design to ensure efficient charge-transfer and electrochemical stability and improved cell mechanical stability.
    - proposed approach shall have no negative impact on energy densities, safety, and cyclability.
    - development of coating strategies for current collectors.
- **For Generation 4b (solid state with Li metal-based anode materials) projects shall cover one or several bullets:**
    - New materials and/or chemistries to increase the energy densities beyond the state of the art of batteries used in electro mobility applications.
    - At the anode side, lithium metal appears as the only choice in terms of gravimetric energy density.
    - Improved reversibility, homogeneity and density of electrodeposition process by doping or coating strategies.
    - Solutions for manufacturing and handling Li metal sheet in dry atmosphere.
    - Novel solutions for low cost manufacturing strategies such as solvent-free electrode manufacturing and solid electrolyte deposition
    - Another technology (anode-less), could also be developed by designing current collectors for reversible electrodeposition of lithium. Current collector coating strategies which regulate lithium deposition and improve cycling performance can also be developed.
    - Solid-state electrolytes and lithium metal anodes open the way to new cathode chemistries reaching high energy density such as lithium-free cathode in combination with lithium metal or Li-excess cathode exhibiting high irreversible capacity in the anode-less configuration.
    - Improving interface design to ensure efficient charge-transfer and electromechanical stability and improved cell mechanical stability
    - Bipolar batteries

C5-D2-BAT-05-2022: Interface and electron monitoring for the engineering of new and emerging battery technologies

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of 5 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 3-4

<u>Expected Outcomes:</u>

State-of-the-art in experimental and computational techniques for characterisation of battery materials and interfaces are targeting the scale of the atoms and ions. Indeed, due to the complexity of interface formation and evolution as a function of time, temperature, battery cycling conditions and a chemical matrix for the electrolytes consisting of different salts, additives and liquid solvents and/or solid components, there is still a lack of understanding hampering the engineering of new and emerging battery technologies. Going into more depth, the process at the time and length scales of the electron transfer reactions remains almost completely underexplored.

Pushing the frontiers of present in situ analytical techniques is a must to more efficiently pursue research on sustainable materials and to develop greener Li-ion as well as future battery chemistries. Improvements in analytical techniques that would allow to follow the movement of interfacial reactions at the molecular scale all the way to the role of electrons at the nanoscale and sub-nanoscale, at relevant timescales and on relevant systems and interfaces, will have great impact beyond the sole battery field and would benefit to the electrochemistry field as a whole, including electrocatalysis and others. It will contribute to open up a new era for the study of transport at interfaces, which remains one of the greatest challenges of research for any electrochemist. For researchers exploring new storage concepts and engineering new interfaces, it will also provide insight into how to control the movement and redox processes of atoms.

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

- New methods for studying electrode/electrolyte interfaces for liquid-based electrolytes and batteries
- New methods for studying solid-state and buried interfaces
- Models for explaining degradation of battery materials
- Increased control of the electronic wiring of electrodes to decrease loss of battery performance due to unwanted side reactions
- Deeper understanding of the redistribution of electronic charge during the redox process can lead to better materials development of both existing and new materials.

<u>Scope:</u>

This topic should support the development of novel experimental and computational techniques targeting the time and length scales of interface reactions in a battery cell including electron and ion localisation, mobility and transfer reactions.

This targets the development of novel analytical techniques, supported by modelling and simulation, able to follow interface, electron and ion dynamics in battery materials and battery cells, and carefully selecting controlled model systems to implement those novel techniques.

Examples of experimental tools include operando Transmission Electron Microscope (TEM), Electron Paramagnetic Resonance (EPR), operando ambient pressure photoelectron spectroscopy techniques, operando X-ray scattering techiniques, NMR, soft X-ray spectroscopy with RIXS, neutron spectroscopy, ultra-fast spectroscopic methods as well as Free Electron Laser (FEL) facilities. Other synchrotron and neutron scattering and ion-beam techniques leading to development of new understanding of interfaces can also to be suggested and implemented. The goal is to give advice and new insights on how to increase the life time and safety of new emerging technologies.

Building upon the BATTERY 2030+: this call topic addresses the need of increasing the fundamental understanding of processes in batteries at a level that will accelerate the development of more stable chemistries adapted for their specific purpose. The proposal should also cover the contribution and collaboration to the the Battery 2030+ large scale initiative.

C5-D2-BAT-06-2022: Furthering the development of a materials acceleration platform for sustainable batteries (combining AI, big data, autonomous synthesis robotics, high throughput testing, for accelerated discovery of high performing battery technologies)

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of 20 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 3-4

<u>Expected outcomes</u>:

Batteries have complex and dynamic processes taking place in and between materials and at the interfaces/interphases within a battery cell. For each new battery chemistry explored, new challenges in understanding these processes are revealed. To accelerate the finding of new material's and their combinations for both existing and future battery chemistries the iterative and fragmented trial and error approach used today needs to be replaced since it is slow and insufficient.

To accelerate the discovery of battery interfaces, materials and new sustainable concepts with high energy and/or power performance there is a need to develop a fully autonomous and chemistry neutral Materials Acceleration Platform (MAP) for battery materials and interfaces. This is a key and long-term challenge for European battery community. The aim is to integrate advanced multi-scale computational modelling, materials synthesis, characterisation and testing to perform closed-loop autonomous materials findings and interphase engineering that would accelerate by at least a factor of five the discovery of new battery chemistries with ultra-high performances.

Building upon the shared data infrastructure, standards and protocols developed in the Battery 2030+ initiative, this call topic addresses the need of increasing the level of autonomy in the MAP-based discovery and development process. The proposal should also cover the contribution and collaboration to the Battery 2030+ large scale initiative.

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

- Demonstrate a fully autonomous battery-MAP capable of integrating computational modelling, materials synthesis and characterisation of both Li-ion and beyond Li-ion chemistries
- Scale-bridging, multi-scale battery interface models capable of integrating data from embedded sensors in the discovery and prediction process, e.g. to orchestrate proactive self-healing.
- Community wide state-of-the-art collaborative environment to access data and utilise automated workflows for integrated simulations and experiments on heterogeneous sites, e.g., exploiting EU HPC architectures and Large-scale facilities in collaboration with LENS and LEAPS.
- Demonstrate a robotic system that is capable of material synthesis for inorganic, organic or hybrid compounds following standard synthesis routes via automated characterisation of intermediate and final products and autonomous decision-making.
- Deploy predictive hybrid physics- and data-driven models for the spatio-temporal evolution of battery interfaces and demonstrate inverse design of a battery material/interface.

Scope:

- Infrastructure tools for secure remote data access, data analysis and predictive modelling: Develop a data infrastructure for raw and curated experimental and modelling data, which can be accessed remotely and securely by relevant stakeholders, including industry. Develop the software infrastructure required to operate this platform, also with regard to future exploitation of the results of the research activities. The software should provide specific access right and allow remote data access, complemented by distributed workflows using software-agnostic workflow engines that provide rapid-prototyping. Inverse materials design using hybrid physics- and data-driven battery interface genome models should also be demonstrated.
- Automated high throughput characterisation and integrated experimental and computational workflows: High throughput, multimodal operando experimental techniques using standardised battery cells and established protocols must be optimised to perform effective screening of new materials and on-line diagnosis of realistic devices. A central objective is to establish, structure, operate and dynamically refine such facility platform to harmonise, mutualise and optimise the global demand for battery characterisation. This includes automated experimental and computational workflows and modules for data acquisition and multimodal/multiscale analysis. Particular attention should be paid to battery interfaces and direct observation of interfaces under dynamic conditions, which are key to improve the performances and the lifetime of batteries.

- Autonomous synthesis robotics and orchestration software: The transition from low/no automated robotics for the synthesis of battery materials requires several R&I steps towards fully autonomous systems. Within the scope of this proposed call are partially autonomous systems following standard synthesis routes for inorganic and organic battery materials, especially also multi-step and high-temperature synthesis, that so far are challenging to automate for high throughput. AI-based orchestration and optimisation software modules and packages specifically targeting battery materials and interfaces are also central to the scope.
- Inverse design and AI-assisted scale-bridging models for multiple time- and length-scale processes: To develop scale-bridging models correctly describing the multiple mechanisms occurring at atomistic scale and the mesoscopic scale on the cell level. The new model approaches should be able to incorporate data from the advanced sensing in virtual design optimisation and battery control algorithms for SoX estimation. Sensitivity analysis and uncertainty quantification of the developed SoX models is also a requirement to assess the robustness of the developed models. These models must achieve a challenge based rational balance of accuracy and computational effort. They should accurately describe the actual state of the system, but also enable diagnosis and prediction, e.g., when self-healing procedures should be initiated. Multiscale Modelling approaches should be developed for the control of safety between BOL (Beginning Of Life) and EOL (End of Life) of a battery system by different uses and diagnosing the safety state of a battery system by innovative methods.

Manufacturing processes

C5-D2-BAT-07-2021: Environmentally sustainable processing techniques applied to large scale electrode and cell component manufacturing for Li ion batteries

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. The EU estimates that an EU contribution between 5 and 8 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-6

Expected outcomes:

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

- Development of new sustainable electrode and cell manufacturing techniques with reduced energy consumption, lower carbon footprint and no Volatile Organic Compounds (VOCs) emissions. Provide EU a leadership position in production of batteries with lower carbon footprint.

- Development of electrode and cell manufacturing processes that are scalable, safer, cheaper, cleaner and less energy consuming compared to state-of-the-art technologies, ultimately reinforcing an internationally competitive European battery manufacturing industry.
- Development of electrode coating production techniques completely eliminating organic solvents as slurry dispersing media leading to avoid the large capital costs associated to the solvent recovery system Implementation of dry manufacturing techniques such as 3D patterning of active electrode layers, and/or hydrophobic surface treatment of electrodes with next generation materials.
- The proposed processes should address the notion of "Design to Manufacture".
- Industrialising closed loops and process design to return low-value chemicals from manufacturing processes to high-value and necessary inputs for the battery manufacturing industry

Scope:

Industrial scale fabrication of Li-ion battery (LIB) porous electrodes imply casting of a slurry over a thin metallic current collector according to conventional coating procedures. This is the technology used also for advanced LIBs with high energy electrode materials and liquid electrolyte (Gen3a/b). The slurry to be coated is prepared by mixing the active material, conductive agent and binder in a solvent, typically N-Methyl-2-pyrrolidone (NMP). Since NMP is toxic in nature, an expensive recovery system must be placed to collect the evaporated NMP in the drying process.

Less expensive and environmentally friendly solvents, such as water are already employed for anode manufacturing, which eliminates the large capital cost of the solvent recovery system. Wet coating technologies can still be further optimised and benefit from reducing the solvent fraction, thus, reducing the energy demand of the drying step. Moreover, completely dry processing techniques could completely remove the need for energy consuming drying, hence reducing the CO2 footprint of the electrode fabrication process.

This may also apply for example to protective interface coatings for both advanced anode – e.g. lithium metal- and cathode – e.g. HV spinel materials. Also, there are other new concepts that can benefit from the implementation of dry manufacturing techniques such as 3D patterning of active electrode layers, or hydrophobic surface treatment of electrodes with next generation materials. The process should be scalable, safer, cheaper, cleaner and less energy consuming compared to state-of-the-art technologies. The proposed/developed processes should address the notion of "Design to Manufacture", which should reduce production cost and increase battery performance resulting in increased efficiency and better cycle life. It should also propose innovative technical solutions and/or standardized approaches to ensure workers and users safety, particularly in the field of handling new materials during processing – such as in the case of nano materials-. The challenge is proposed for Li-ion up to generation 3.

Projects shall be aligned with H2020 project LiPLANET initiative – The EU network of R&D Li cell manufacturing pilot lines.

Manufacturing processes

C5-D2-BAT-08-2021: Manufacturing technology development for solid-state batteries (Generations 4a - 4b batteries)

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between 6 and 8 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-6.

Expected outcomes:

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

- Generation of an indigenous technological knowledge portfolio of industrially scalable manufacturing solutions for the different approaches to SSB including all core components: electrolytes, anodes –either carbon or Li(m) based - and their ad hoc composites cathodes.
- Position Europe at the industrial production lead in the international race for next generation, solid state battery (SSB) technologies all through the value chain.
- Contribute to decarbonise transport via the development of breakthrough technology in SSB batteries.
- Enable cost effective, low carbon footprint mass production of Gen4 technology in EU.

Scope:

Lithium ion battery cells with conventional active materials are reaching their limits in terms of energy densities. Also, safety issues arise with the utilisation of liquid organic electrolyte which are becoming even more critical with the nearly introduction of advanced materials made to increase cell voltage and fast-charging rates, therefore requiring the replacement of current conventional flammable liquid electrolytes. Hence, there is an urgent need for the development of innovative scalable manufacturing technologies based on of new solid electrolytes that can be also combined with metallic lithium at the anode, leading to significantly enhanced energy density. In that context, solid-state electrolytes enable overcoming current battery cells limitations in terms of voltage and safety (reducing dendrites formation risk) leading to and increased intrinsic thermal and electrochemical stability.

As a consequence, in parallel to the progress in new materials developments, there is a growing need of Research and Innovation addressed to develop appropriate processing techniques for assemble cells based on solid type electrolytes including all current foreseen technological options: polymer-based, hybrid polymeric, inorganic and other alternatives such as gel-like semisolid electrolytes.

Also, processing, handling and integration of lithium metal anodes into cells, with special attention to solid-solid interfaces and protection layers need to be tackled (Generation 4b). As an alternative route, advanced Si/C composite-based anodes (Generation 3b) may come as a possible solution, and their specific manufacturing approach and interface requirements towards solid state electrolytes should be covered as well. Thus, appropriate processing techniques must be developed, optimised, adapted or reinvented for the preparation of dense electrode and electrolyte layers, to enable scale up of solid-state battery cells (Generation4a and Generation4b) towards industrial GWh mass production.

Cathodic electrodes making use of advanced materials – e.g. high Ni content oxides-combined with electrolyte material to enhance interfacial compatibility may pose specific manufacturing challenges involving innovative dry and/or extrusion coating techniques.

Projects funded under this topic should make provisions to establish adequate coordination schemes with related materials running projects, with special focus in C5-D2-BAT-04-2021= Advanced high-performance Generation 4a, 4b (solid-state) Li-ion batteries.

The new manufacturing techniques for the SSB Gen 4a/4b batteries should focus on cost, performance, safety and sustainability with clear prospects for cost-competitive large-scale manufacturing and uptake by the electro mobility sector. Also, as the manufacturing techniques may benefit from digitalization, and moreover be ready to be integrated in digitally-driven larger production lines, project proposals should address digitalization within their scope. Manufacturing and cell assembly processes to be developed should be more sustainable compared to the current LIB manufacturing.

Focus is into manufacturing technology development, up to pilot-level proof of concept. Activities to be aligned/feeding into the specific machinery development topic –industrial machinery development is beyond the scope of this topic-.

Topic to be also strongly aligned with the specific topic on SSB advanced materials development.

C5-D2-BAT-09-2022: Towards creating an integrated manufacturing value chain in Europe: from machinery development to plant and site integrated design

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between 6 and 7 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 6 (for machinery development) and TRL 7 (integration of manufacturing plant supply chain).

Expected outcomes:

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

- Strengthening Europe's battery cell industrial manufacturing value chain by building-up its Giga scale manufacturing capabilities distributed in the member states territories.
- Development of new battery cell manufacturing machinery, with priority on minimising energy needed for cells production, enhancement of plant efficiency rates and integration of intelligent control processes to minimise scrap.

- Enabling deeper collaboration between (i) battery process equipment companies (ii) industrial-scale cell manufacturing, (iii) material, energy and other supply chain sectors benefitting from sector coupling.
- To stimulate and intensify the collaboration between pilot line operators, industrial-scale academia, cell manufacturing companies and European equipment companies to push innovations with regard to an economically and ecologically sustainable cell production in Europe.

Scope:

In order to build globally competitive Li ion battery (LIB) cell production plants in Europe, all the production value chain from machinery to plant and site development and optimisation must be considered holistically, from machinery development to plant and site integration and optimisation. This topic intents to cover both areas.

In recent years Europe has developed strong competences in Li ion battery technology with regard to academic research, material development and Battery system design. However, there is still a lack of knowledge and competence regarding the economically and ecologically production of LIB cells in both high volumes in Giga-factories or in much smaller batches for specialised applications as developed in Mega-factories. From this perspective, the scope of this topic is two-fold:

- From one side, to be able to supply machinery which is developed and built locally, Europe has to develop a leading position in the production of resource efficient, intelligent electrode and cell manufacturing machinery.

In the development of such battery manufacturing machinery, important aspects for success include: minimising energy consumption, eliminating air and water pollution and integration of intelligent control processes to minimise scrap thus reducing costs and environmental impact of the production process. In addition, such machinery must operate at very high productivity levels with incorporate intelligent quality control systems. Moreover, strategies of industry 4.0 should be intensively integrated in new European cell production plants to yield economic success.

Activities under this topics would cover from TRL 3 (start) to TRL 6 (target).

- From the other side, battery cell production as a whole is currently confronted with enormous cost pressure. One major factor in the cost structure of European Giga-scale battery cell production is related to highly energy consuming manufacturing processes. A significant reduction and/or utilisation of low-carbon energies would not only bring economic benefits, but would also provide clear advantages in terms of the ecological footprint. For sustainable success, the horizontal integration of the European supply chain for battery process equipment into the growing production of giga-scale battery cells is a major challenge.

  Activities under this topic would cover from TRL 6 (today) to TRL 7 (target).

Hence, this proposed topic aims at closing a gap and enabling deeper collaboration between industrial-scale cell manufacturing, battery process equipment companies, and material and other industrial sectors potentially benefitting from sector coupling with cell manufacturing (e.g. grid power or material suppliers)**.**

Therefore, existing cell production lines and their material and energy flow internally and externally interaction with other companies at the site should be investigated and evaluated. Based on this, the network should investigate the ecological impact of different machinery, production line configurations and factory designs to come to best practice proposals. Another challenge is to implement ecological standards along the production chain together with material suppliers and factory operators.

One additional target to achieve these goals is to stimulate and intensify the collaboration between pilot line operators (e.g. which shall be organised within the LIPLANET network), industrial-scale academia, cell manufacturing companies and European equipment companies to push innovations with regard to an economically and ecologically sustainable cell production in Europe. This includes the support from running activities including for example IPCEI's on batteries.

Battery Systems

C5-D2-BAT-11-2022: Next generation technologies for high-performance and safe-by-design battery systems for transport and mobile applications

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. The EU estimates that an EU contribution of between 5 and 7 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5

Expected outcomes:

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

- next-generation battery system technologies for electrification of a broad range of transport and mobile applications (including road, waterborne, airborne, and rail transport, as well as non-road mobile machinery)
- demonstrating increased performances (energy density, power density, lifetime) and safety of battery systems, to improve the competitiveness of the European battery industry in the transport market;
- novel design and process to reduce manufacturing, refurbishment, dismantling and recycling costs of battery systems.

Scope:

Batteries are key for decarbonising the transport sector, which represents around 25% of the total CO2 emissions in the EU. The electrification of transport and mobile applications require high-performance and safe battery systems. In particular, fire is a critical safety risk for several transport modes.

Projects are expected to develop innovative battery systems technologies that will benefit several transport and mobile applications, by significantly improving performances and safety, as well as environmental sustainability and cost.

In order to leverage the full potential of the research ongoing in Europe at the battery material and cell levels, projects should consider the adaptation of battery system design to novel cell chemistries that will reach the market in the short-to-medium term (e.g., advanced lithium-ion or solid-state cells). Enhancing the cell-on-system volume ratio and/or weight ratio will increase the energy density and/or power density at the battery system level. More generally, projects should consider new technologies (battery system materials, mechanical design, electrical architectures, thermal management strategies, etc.) for enhancing performances and safety (for example, novel lightweight materials with optimum thermal characteristics to decrease battery module and pack weight and simultaneously enhancing safety; new dielectric cooling liquids with enhanced fire-retardant properties; etc.). Manufacturability and recyclability should be explicitly addressed, in order to reduce the manufacturing, refurbishment, dismantling and recycling costs as well as the carbon footprint of the new battery systems.

The projects should 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) is out of scope for this topic, but obviously projects shall foresee requirements of the chosen use cases.

Projects should cover one or several use cases among the main transport or mobiles applications (such as road, waterborne, airborne and rail transport, as well as non-road mobile machinery and industrial applications), with the aim to maximise the impact on the European industry and on CO2 emission reduction. Projects may consider the key performance indicators proposed by Batteries Europe or by the dedicated Partnerships, reflected in the Partnership SRA, to guide the technology developments on the application segments and use cases that will be selected. Some of the project results can also be relevant for stationary energy storage applications.

C5-D2-BAT-12-2021: Physics and data-based battery management for optimised battery utilisation

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. The EU estimates that an EU contribution of between 5 and 7 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4.

Expected outcomes:

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

- significant advances in the state of art of battery management systems;
- new physics and data-based approaches for battery management, with the potential to enhance performances, lifetime, reliability and safety of battery systems for transport and stationary applications.
- new physics and data-based approaches for battery management facilitating predictive maintenance, and/or knowledge-driven end-of-life management of battery systems, and/or the development of more accurate degradation models.

Scope:

Battery management plays an essential role by ensuring an efficient and safe battery operation. However, current battery management systems (BMS) typically rely on semi-empirical battery models (such as equivalent-circuit models) and on a limited amount of measured data. Consequently, there is currently a lack of knowledge about the overall state of the battery in operation, resulting in suboptimal utilisation.

Projects are expected to substantially advance the state of the art in the field of battery management, by developing innovative physics and data-based approaches, both at the software and hardware levels to ensure an optimised and safe utilisation of the battery system during all modes of operation.

Projects should pave the way towards next-generation BMS, which will leverage on an increased computational capability enabling the execution of advanced software, and on the ability to acquire, communicate and analyse large amount of data. Those next-generation BMS will lead to significantly enhanced performances, lifetime, reliability and safety of the battery system, by a dynamic update of battery usage limitations and the possibility to widen the battery operating range in a controlled manner. Moreover, they will provide open access to an increased amount of data (which can possibly be processed offline), enabling the development of effective degradation models (thus reducing the investments costs of storage systems by mean of improved sizing during the design phase), and facilitating predictive maintenance and end-of-life management.

Projects are expected to develop technologies at both the software and hardware levels, with a validation through a lab-scale prototype at TRL 4. Several of the following items should be addressed: the development and implementation of physics-based battery models (e.g., ageing phenomena models); adaptable battery models (e.g., based on operation data); sensor-based solutions at the battery system level (e.g., with respect to sensor integration, communication with the battery management, data fusion, data analysis); advanced state estimators (e.g., state of health, state of function, state of energy, state of power, state of safety); methods for the prognosis of remaining useful lifetime and ageing; methods for the early detection or prediction of failures; solutions for the management of special situations (e.g., unbalanced or dysfunctional cells). Project results should be applicable to a broad range of transport or stationary applications.

C5-D2-BAT-13-2022: Embedding smart functionalities into battery cells (embedding sensing and self-healing functionalities to monitor and self-repair battery cells)

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. The EU estimates that an EU contribution of between 8 and 10 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 2-4.

Expected outcomes:

Batteries are operating in different conditions and although preventive approach during battery operation is a must, we need to develop curative functionalities which would enable battery operation in different non-ideal conditions while being transparent through the nasty chemical environment of the cell. Smart functionalities with sensing developed to detect irreversible reactions and self-healing functionalities designed to repair damage occurred within the cell, Europe can develop cells with much higher quality, better reliability and longer cycle life. This call is building on the long-term research roadmap of BATTERY 2030+. The proposal should also cover the contribution and collaboration to the Battery 2030+ large scale initiative.

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

- Increased quality, reliability and life (QRL) of the battery system by extending the lifetime of the battery cells and maximising their performance
- New self-healing components for future battery systems to ensure a larger and longer-lasting safety characteristics at battery cell level.
- Industrial opportunities for exploiting new concepts and technologies for integrating sensing and self-healing capabilities in the battery cell.

Scope: The target of this call is to embed sensors and self-healing functionalities into single battery cell, with sensors being capable to detect defective operation and trigger self-repairing functionalities via the Battery Management System (BMS).

Proposal should aim at combinatory approach based on the development of sensors with functionalities capable of continuous, long term operation within the cell and on the development of self-healing functionalities which can be triggered by external stimulus. Sensors and self-healing functionalities need to be adapted to detection of the critical degradation processes during cell electrochemical or chemical ageing. Different battery chemistries can be addressed with a focus on most critical degradation processes.

Proof of concept of coupling sensors and self-healing agents via BMS should be demonstrated. Clear benefit of embedding smart functionalities into battery cells should be demonstrated and approach needs to be adaptable to battery cells mass production processes and not hinder subsequent recycling process. Estimation of QRL over the life span should be assessed and the competitive advantage over alternative approaches like replacement or recycling or second-use should be demonstrated.

Building upon the BATTERY2030+ roadmap: this call topic addresses the need to develop new sensors and self-healing functionalities which can give the batteries of the future increased life-time, efficient re-use and better commercial success. The benefit of these innovation on the global battery safety should be demonstrated. The proposal should also cover the contribution and collaboration to the Battery 2030+ large scale initiative.

C5-D2-BAT-14-2022: Digitalisation of battery testing, from cell to system level, including lifetime assessment

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-6.

<u>Expected outcomes:</u>

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

- competitiveness of the European battery industry across the value chain (from cell manufacturers to cell integrators);
- shorter time-to-market;
- reduced time and/or cost of battery development by at least 20% to 30%;
- improved battery design, for longer lifetime, and better reliability and safety.
- reduced investment and operational costs of battery systems

<u>Scope:</u>

The current way of developing batteries is mainly based on trial-and-error processes, which are time consuming, costly, and do not always lead to the best product design. It is particularly the case when it comes to testing batteries to assess their performance, lifetime, reliability and safety. Existing methods and tools lead to high costs, because of long test durations, and/or the high number of required test samples, and/or the use of costly test infrastructures. There is a significant room for improvement, by relying on digital methods and tools to minimise the use of standard trial-and-error processes. Digitalisation of battery testing will lead to an acceleration of the battery development time, a higher quality of the battery assessment (better evaluation of battery performances, lifetime, reliability and safety), and an improvement of the battery design itself (by better adapting the design to the application requirements and production capabilities) and a better estimation lifetime (by better modelling of battery ageing). Improvement in battery testing will result in major cost savings, in particular in the development phase (test before invest).

Projects are expected to provide novel methods and tools to accelerate and improve the battery testing process. A multi-scale approach should be used, by covering the value chain from battery cells to battery systems (here, a battery system refers to an energy storage unit integrating battery cells, excluding power converters). Projects should propose and validate a new paradigm based on intelligent design of experiment (to avoid duplicated experiments, or experiments that give low-quality information), the smart combination of physical and virtual testing, hardware in the loop solutions, and the development and use of advanced models describing battery cells and systems (physics-based models, data-driven models, or hybrid models) and the relevant expected evolution in multiple different conditions of usage. A particular attention should be paid to the assessment of battery lifetime, reliability and safety, including the development of innovative methods for testing of safety in transport and safety in usage, based on representativeness of the method for the various potential failures (failure initiation, propagation control, mitigation means, etc…).Projects should have an ambition for cross-sectorial applications, and should focus on battery chemistries currently on the market or that will reach the market in the short term (i.e., advanced lithium-ion chemistries), with the potential to quickly adapt to next-generation battery chemistries (i.e., solid-state lithium-based chemistries).

Recycling technologies

C5-D2-BAT-15-2021: Streamlined collection and reversed logistics, fully automated, safe and cost-efficient sorting, dismantling and second use before recycling

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-7.

<u>Expected outcomes:</u>

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

- Achieving the objectives of the Circular Economy by enabling second life of batteries and increasing rates for recycling and recovery, in line with upcoming regulatory requirements;
- Revolutionize and re-freshen recycling industry, by applying best-in-world innovations based on automatisation, efficiency and sustainability.
- Create new circular business models, such as second life, to reduce the need for primary raw materials, and to maximize the use of battery cells reducing the cost per cycle.
- Develop a community for actors involved in the management of the recycling value chain for batteries (including second life) for sharing best practices (health and safety, transport, dismantling, refurbishing, recycling).
- Improve safety, through automatisation and reducing accidents.

<u>Scope</u>:

Today the amount of end-of-life (EoL) batteries from e-mobility and stationary applications is still limited. Moreover, EoL batteries are not standardised (form, chemical composition, etc.) and consequently, their management and recycling are mainly based on manual process. This increases risk of accidents as the integrity of the batteries / cells is no longer guaranteed.

Within next several years, the amount of EoL batteries will surge, transforming the recycling and battery value chain in general. It is important to develop efficient recycling chain and processes able to meet these upcoming amounts of diversified waste streams. A general approach to recycling shall thus be reconsidered and new sustainable recycling chain for batteries shall be established, in terms of introducing novel approaches to products, processes and keeping in mind their socio-economic viability and environmental impact.

It will require new techniques and concepts for collection, logistics, and automatisation in sorting, dismantling and second use before recycling.

Proposals shall cover all aspects below:

- Develop common diagnostics protocols and cut-off criteria between product (2nd life application) and waste (recycling);
- Elaborate critical stage of diagnosis of batteries as a waste-prevention measure in order to define which batteries or components of batteries are still considered fit for a second life application.
- Automatise the dismantling of E-mobility and stationary batteries and reduce costs by avoiding manual work and improving sorting of parts for their replacement or prepare for recycling allowing the selective extraction of materials including the cathode and anode materials which for certain Li-chemistries lead to a higher value creation for the downstream recyclers.
- Development of novel safe dismantling processes and safety procedures along all steps of EoL management chain with focus on battery burning process (thermal runaway), identification of Limiting Oxygen Index (LOI) and Lower Explosive Limits (LEL)
- Development of technologies preventing or reducing thermal runaway during transportation, storage and dismantling of batteries.
- Design and demonstration of standardized and cost-efficient storage and transportation containers with visual and thermal load monitoring systems and, if necessary, inert atmosphere or other measures reducing risk of fire or thermal runaway.
- Development of technologies for fast and efficient discharge of used batteries, connected with energy recovery, possibly integrated with SoH diagnostic equipment, with flexible connectivity and adjustable to various kinds of batteries.
- Development of standardized battery labelling system enabling all interested parties to automatically obtain necessary data on each battery. Potential integration of labelling system with battery passport database project and with labelling systems from other regions of the world (e.g. China). Identification of necessary data that should be included into labelling and battery passport projects.
- Research on batteries sorting and dismantling technologies, particularly automated sorting including machine learning applicable to small and EV batteries.
- Identify all potential risks and develop safe processes and safety procedures to reduce accidents.

C5-D2-BAT-16-2021: Sustainable, safe and efficient recycling processes

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between 6 and 8 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-6.

Expected outcomes:

Projects are expected to contribute to the following outcomes:

- Improved access to battery materials and strengthened European raw material independency by increased circularity of material flows and use of the secondary raw materials in new batteries produced in Europe;
- Increased European competitiveness offering sustainable, safe, energy efficient and low carbon footprint battery recycling technologies and upscaleable solutions.
- Reduced recycling cost and environmental impacts through new and disruptive concepts for very high efficiency recycling;
- Improved health and safety aspects of recycling;
- The industry is prepared to meet the new regulatory targets for the recycling

Scope:

In order to effectively exploit the vast amounts of EV and stationary battery waste emerging in the next decades, as well as the increasing amounts of production scrap resulting from larger manufacturing, it is important to create innovative feasible and holistic recycling processes in Europe.

Newly developed recycling processes shall be more flexible and adaptive, to be able to meet a wide variety of battery waste or production scrap resulting from cross different Li-battery chemistries (i.e. with and without transition metals). It is desirable to implement intelligent process design through integrating selected fractions into existing industrial infrastructure, or other innovative integration of fractions or processes. The recycling processes may partially utilise existing metallurgical infrastructure of the primary materials to support feasible processing and explore ways to support industrial transition towards green technologies.

Newly developed recycling processes shall aim at recovering the highest amount of resources (metals, graphite, fluorinated compounds and polymers) present within secondary raw materials which result from spent Li-batteries with and without transition metals and focus on the reuse of these materials in batteries.

Low-value chemicals from manufacturing processes should be returned to high-value and necessary inputs for the battery manufacturing industry. Focus shall, however, be on developing materials recycling routes which as directly as possible target next-generation battery cathode and anode materials. Vertical integration to component/cell manufacturing shall be improved.

Proposals shall aim at the outmost recovery rates and recovered material purity, meeting industrial requirements for their integration in the loop of cell manufacruting, in line with values reflected in Partnership SRA.

Recovery/re-use/reconditioning of battery materials/electrodes/components shall also be maximised and recycling discharge minimised.

Proposals shall develop new unit processes, or innovative combinations of optimised unit processes, including, but not limited to mechanical pre-processing, leaching, precipitation, solvent extraction, ion exchange, crystallisation, electrowinning, roasting, smelting, pyrolysis, and direct reuse of materials and components.

Proposals shall identify and address health risks, environmental impacts, safety hazards and new safety practices related to developed processes.

The environmental impacts and benefits are to be quantified through life cycle thinking approach (e.g. LCA/SLCA), also in collaboration with the project funded under the joint topic 2ZERO-BAT-20

The co-operation with projects funded under topics C5-D2-BAT-01 and C5-D2-BAT-02 shall be established.

Cross-cutting topics - *Coordination*

C5-D2-BAT-19-2022: Coordination of large-scale initiative on future battery technologies

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of 3 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

Expected outcomes:

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

- Fostering the scientific, technological, economic and societal impact of the initiative and paving the way to industrial exploitation of future battery technologies in key energy and transport application domains
- Well-coordinated European research initiative on future battery technologies gathering excellent scientists and innovators as well as involving other relevant stakeholders and linked with relevant international, national and regional programmes.
- Spreading of excellence in future battery technologies across Europe, increased awareness of European activities and availability of European curricula in the field.
- Increased synergies and collaboration between the relevant research and innovation stakeholders in Europe as well as with major initiatives that already exist or are under preparation.

Scope:

This call topic aim to network and coordinate the Battery 2030+ large scale research initiative on Future Battery Technologies and its contribution to the broader efforts of the European research and innovation stakeholders in battery technologies foreseen at European level and in the Strategic Energy Technology (SET) Plan and to tackle long-term research challenges expected to result in 'game changing' impacts on future battery technologies paving the way for providing a technological competitive advantage to the European battery industry. Because of their ambition, their scale and their interdisciplinary nature, these challenges can only be realised through a long-term, coordinated and sustained effort at European level, by building on large scale research cooperation across academia and industry and with other research initiatives at regional, national and European level, and by mobilising Europe's best researchers around an ambitious long-term research agenda.

Proposals are expected to coordinate the research activities and the stakeholders participating in the initiative; to facilitate communication, dialogue and cooperation on crosscutting topics; to monitor the initiative's progress and maintain its roadmap; to provide support for its governance; to promote and communicate the objectives of the initiative and its achievements, including by ensuring media presence and public visibility, by engaging with industry and society and by participating or organising outreach events; to identify training and education needs and promote European curricula in future battery technologies. In particular, proposals should identify and coordinate relevant efforts for modelling and data sharing, standardisation, IPR actions in cooperation with other relevant initiatives at European level. They should also help networking and collaboration with other relevant national and international activities in the field. They should cooperate with Batteries Europe, the ETIP on battery announced in the EU Strategic Action Plan on Batteries.

It is expected that such an activity is driven by representatives of the relevant actors of the field (e.g., from academia, RTOs and industry).

C5-D2-BAT-20-2021: Support for establishment of R&I ecosystem, developing strategic forward-looking orientations to ensure future skills development, knowledge and technological leadership for accelerated disruptive technology exploration and uptake

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of 3 million EUR would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

Expected outcomes:

In order to succeed in the development of a thriving innovative battery industry, pan-European cooperation on research and innovation is essential. It is not only essential to work across geographical boarders and institutional levels but it is also crucial that stakeholders from all parts of the battery value chain pull together in a strategic coordinated manner to ensure our collective research efforts are efficiently translated into sustainable technologies and products economically, environmentally and socially.

Europe has an extensive landscape of battery R&I stakeholders. Thus there is a need to continuously consolidate the Battery R&I community across the EU and associated countries and across Battery-related networks, projects and initiatives (including European, national, regional – HEU Partnerships, IPCEIs, Interregional partnership on advanced battery materials, European Battery Alliance and coordination actions including Battery2030+, LiPLANET,) Project results are expected to contribute to all/ of the following expected outcomes:

- Consolidated Battery R&I community across the EU and associated countries and across Battery-related networks, projects and initiatives (including European, national, regional – HEU Partnerships, IPCEIs, Interregional partnership on advanced battery materials, European Battery Alliance and coordination actions including Battery2030+, LiPLANET, and other initatives established until the project end).
- Facilitated access to information for all – enabled European "one-stop shop" on Battery R&I information, including information on national programmes, events, battery projects and national battery networks (via website and other communication channels) reaching as many as possible battery stakeholders.
- Increased time to market of technologies and improved European competitiveness through established research-industry collaborations, information sharing and expert group work.
- Synergies and research results efficiently shared along the whole value chain, thus mobilizing R&I efforts.
- Attracted talent and competences necessary to achieve the technical goals and to support European industry
- Provided scientific evidence for policymakers.
- Increase international collaboration

Scope:

- Develop, consolidate and communicate a strategic research approach for all stakeholders throughout the entire European Battery Value Chain.
- Develop and/or update coherent Strategic Research and Innovation agenda (SRIA) and corresponding detailed roadmaps covering all aspects of the battery value chain through expert group work.
- Facilitate and support work of experts from a different field in a cross-collaboration manner, identify the challenges and opportunities and so create guidelines and recommendations on how best to develop synergies.
- Establish and continuously update Key performance indicator (KPI's) values for current state-of-art battery technology, as collected from stakeholders across the battery value chain correlated and communicated via SET Plan progress monitoring.
- Establish Target Key performance indicators (Target KPI's) values for future battery R&I as collected from all relevant forums, correlated and communicated via SET Plan progress monitoring and the Strategic Research and Innovation agenda (SRIA) to the entire R&I community in general.
- Communicate and implement uniform standards and methodologies for the reporting of battery research developments across EU and national projects building on existing European and national work/efforts.
- Execute a clear communication plan describing the hosting and updating website, organising events and facilitating networking. Communicate results and progress in Battery R&I on both a European and International level.
- Promote and facilitate international collaborative actions, where necessary

- Perform additional activities which are relevant to reach the expected outcomes.
- In order to ensure high quality coordination and technical outputs from the proposals should possess both technical and operative expertise.
- The overarching European R&I platform should build on previous efforts and continue to foster pan-European active cooperation and maintain up-to-date clear realistic strategic research and innovation agenda for Europe.

C5-D5-BAT-ZERT-20-2021: LCA and design for sustainable circularity - holistic approach for zero-emission mobility solutions and the related battery value chain [25]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 4 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

<u>Expected outcomes</u>:

Projects addressing this BAT-ZERT Joint Call shall approach a commonly accepted Life Cycle Assessment (LCA) of zero-emission road transport solutions, focussing on zero-emission vehicles and their batteries, as one of their central components, as well as other applications of the same types of battery cells (e.g. industrial, stationary applications etc.).

Proposals shall foresee coordinated activities on LCA and LCI at vehicle and cell levels, to define and develop a unique and shared approach with common methodologies for both zero-emission vehicles and the battery value chain. The project’s main governance (e.g. Steering Group or Advisory Board) shall foresee direct involvement of relevant stakeholders from the Automotive and Battery sectors, as well as relevant EC services (in particular JRC, RTD, CLIMA, ENV and GROW).

The project’s results are expected to contribute to all of the following expected outcomes:

- A consensus concept for a harmonised, robust, transparent and real-data based LCA approach and tools (also with consideration for extension to social Life Cycle Assessments, S-LCA), with an emphasis on zero-emission vehicles (ZEV) and batteries; enabling the assessment of the sustainability performance and evaluation of optimal designs along the value chain and over the full life-cycle (cradle-to-cradle), also taking into account the need of comparing with conventional solutions;
- New, holistic and applicable quantitative tools to drive an approach to the design of ZEV, their components and batteries;

[25] The identical topic is incuded under Destination 5 (ZERT). In the final draft WP, the topic will appear only once.

- A harmonised strategy for sustainability by design, describing requirements and specifications of tools for all life-cycle phases required to improve the environmental performance of ZEV and batteries, including their components and sub-systems;
- A commonly accepted ontology for a European-wide Life-Cycle Inventory (LCI) database for zero emission vehicles and batteries, including all sub-systems and components, and using real data for the present and short-term future, whilst using provisional data, based on trajectories for the reduction of GHG emissions in the Power, Industry and Transport sectors, and use cases, including pre-defined data quality indicators;
- Greater environmental sustainability and lower TCO (total cost of ownership) through consistent and frontloaded real-data based assessment of technologies and solutions, with extension to other sectors using the same cells and technologies;
- Alignment of on-going harmonisation and standardisation activities relevant for a road transport-specific LCA approach, with emphasis on ZEV and the related battery value chain;
- Increased awareness and acceptance of a European-wide, battery and road transport-specific LCA approach and LCI database.

Scope:

In order to make the best, most informed choices in terms of sustainability, it is of utmost importance for zero emission road transport to have the right tools to assess technologies, non-technical measures and product life cycle processes in a holistic way. In selecting the right technologies for clean and sustainable mobility at a system, vehicle and component level, the ecological footprint and the impact of technologies upon society have to be assessed, based on highly reliable data at an early stage of development and planning in a harmonised and comparable way.

Proposals are expected to address the following:

- Elaborate a consensus LCA (and S-LCA) approach specific for zero-emission solutions, with an emphasis on ZEV and the related battery value chain, suitable for the full life-cycle (cradle-to-cradle) whilst expanding the existing complexity of an environmental LCA to assess and compare the impact of solutions in a holistic way, and reflecting the needs of a resource-efficient circular economy;
- Elaborate the baseline for a Europe-wide, commonly accepted, transport sector LCA approach and LCI (life cycle inventory) database for ZEV and the related battery value chain, based on real data or on provisional data based on trajectories for the reduction of GHG emissions in the Power, Industry and Transport sectors, ensuring openness, accessibility and transparency, implementing the FAIR data principles[26], whilst ensuring applicability to existing technologies;
- Harmonise across all stakeholders for methodologies, tools and datasets, as well as for target criteria, to help improve consistency, robustness and transparency, and to

[26] Final Report and Action Plan from the European Commission Expert Group on FAIR Data, "TURNING FAIR INTO REALITY" - https://ec.europa.eu/info/sites/info/files/turning_fair_into_reality_0.pdf

address important gaps in transport-specific LCA and LCI, with focus on ZEV and the battery value chain. It is of utmost importance to involve all stakeholders, including the EC services, Member States and standardisation bodies, to ensure the acceptance and succeeding implementation of the LCA approach and LCI database;

- Screening, collecting and evaluating of existing LCA and S-LCA needs, methodologies, tools and datasets, to identify and overcome knowledge gaps, to identify development needs in current methodologies and tools, as well as to identify the impact reduction potential for ZEV and batteries;
- Conceptualise the frontloading of a LCA and S-LCA for ZEV and the related battery value chain, at an early stage of development and planning, in a harmonised and comparable way, ensuring the compatibility and comparability with (conventional) alternatives;
- Definition of use cases for ZEV and batteries, representative of real-world conditions (e.g. for activity, lifetime, impacts linked to the specific duty-cycle and accounting for user behaviour) and the exemplary characterisation and calculation of impacts from zero-emission vehicle components, through applying the consensus LCA approach.
- Elaborate the potential and outline the transfer of the consensus LCA and S-LCA for other applications, such as fuel cells or stationary battery systems, or markets such as aerospace or maritime;
- This work should build upon both recent existing EC and stakeholder funded research (in particular the eLCAr project and the DG CLIMA Report "Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA"), and on-going activities within this context shall be aligned towards a single LCA approach.

<u>Communities and cities</u>

This work programme contains only a few activities. The bulk of activities related to communities and cities will be introduced during 2021 as an update to the Horizon Europe work programme 2021, once the preparatory phase of the Horizon Europe Missions has been concluded.

C5-D2-CS-11-2022: CIVITAS 2030 – Coordination and support for EU funded urban mobility innovation

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

<u>Expected outcomes</u>: Projects are expected to contribute to the following outcomes:

- Increasing the extent and speed of the take up of innovative, replicable urban mobility solutions in Europe, targeting responsible authorities and other stakeholders, in order to contribute to the priorities of the European Green Deal, which stresses that ‘’transport should become drastically less polluting, especially in cities. A combination of measures should address emissions, urban congestion, and improved public transport’’:

- Develop, and put in place a communication, dissemination and promotion strategy that will clearly distinguish the identity of the CIVITAS initiative amongst other European city initiatives.
- Provide a common communication and dissemination framework for the projects funded, including providing a common corporate identity and producing a monthly newsletter that includes project results as well as wider developments in the field of sustainable urban mobility
- Reach out to national transport press correspondents and relevant European media, the Horizon project community and a wider European and international audience of cities and professionals with the aim of increasing the visibility of the network and urban mobility projects;

- Providing coordination, monitoring and support activities to the living lab cities and projects funded under CIVITAS, among others by formalising the collaboration with each project through an MoU, and by providing a common realistic and user-friendly evaluation framework with dedicated support to the projects;
  - Facilitating exchanges among the CIVITAS projects and living labs and with the European Commission with the aim of disseminating project results, key milestones and achievements
  - Organising capacity building, training sessions and three site visits per year, based on latest results and best practices from the CIVITAS or other European projects, to support the take up of innovative mobility solutions
  - Organise a CIVITAS Forum to share results and best practice from urban mobility projects
  - Collaborate on the organisation of the Urban Mobility Days (flagship conference on innovative, clean and integrated urban mobility and transport)
  - Looking at project results as well as wider developments in the field of sustainable urban mobility, European media outlets, of cities and professionals
  - Update and increase the database of subscribers of CIVITAS newsletters by 20% every year
  - Offer liaison activities, collaboration and synergy building with the different urban mobility communities and initiatives at European level, such as the ELTIS, EIP SCC, Driving Urban Transitions Partnership, EIT Urban Mobility and the Climate Neutral and Smart Cities Mission;
  - Maintaining, optimising and promoting the CIVITAS website through usability tests, and improving its functionality, to ensure that it remains the main platform for the dissemination of relevant EU urban mobility innovation results increasing the minimum of unique visitors with 10% every year
  - Increase the CIVITAS twitter followers by 20% every year
  - Preparing two policy papers per year on innovative solutions, good practices, and their replication, putting in place ad-hoc three Thematic Groups (based on

the thematic areas of CIVITAS) to analyse developments and prepare recommendations, and organising two meetings per year of the CIVITAS Policy Advisory Committee, with one policy paper issued per year, to facilitate a continued dialogue between cities, businesses and civil society;

   - Prepare policy recommendations and key learnings addressed to cities, Member States and the European Commisison based on research and innovation as well as results from ongoing projects.
   - Updating, promoting and enlarging the CIVITAS cities network, with at least 20 new European cities added per year, providing support and funding to CIVINETS, maintaining the secretariat for the CIVITAS initiative, and actively engaging with local, regional or national stakeholders, aiming to overcome language and other barriers.

Scope:

Together with intiatives of ELTIS and the European Mobility Week, CIVITAS is part of the EU policy on urban mobility as a key flagship encouraging innovation at local level. Since 2002 it acts as an open platform that facilitates research, the uptake of innovative solutions, the validation of research results, the exchange of knowledge and best practices, and common learning in the area of urban mobility and transport. The project selected under this topic will help to ensure the long-term support for the CIVITAS projects offering governance, and an organisational and logistical framework that guarantees the wide dissemination and take up of urban mobility project results.

Proposals should aim at focusing activities on communication and event organisation and coordination of living lab activities continuing and enhancing the operation of the platform, to facilitate the continued coordination and knowledge exchange between the urban mobility projects that have been, or that will be funded under the CIVITAS initiative. These projects will deliver solutions that help achieve climate neutrality in cities, covering both personal mobility and goods/urban logistics using all transport modes.

Proposals should aim at putting in place a common communication and dissemination strategy to maximise the impact of the CIVITAS initiative. Proposals should ensure the monitoring of activities, events and results of the urban mobility projects and communicate about their progress and achievements. Proposers should also consolidate the common ‘CIVITAS Process and Impact Evaluation Framework’ and ensure the continuity of the CIVINETs. They should ensure continuity and provide a smooth transition from the previous Coordination and Support Action, CIVITAS ELEVATE.

C5-D2-CS-16-2021: Co-Funded Partnership: Driving Urban Transitions to a sustainable future (DUT)

Expected impacts:

- Strengthen Europe as a role model for R&I on sustainable urban development through a European urban R&I reference platform supporting cities in their systemic transformation towards sustainability and climate neutrality;
- Enhanced multi-level cooperation and alignment on R&I on sustainable urban development across and within cities, regions and countries, including international outreach and cooperation with other networks and initiatives;

- Innovative, cross-sectoral and inclusive governance, policy and decision-making harnessing the full potential of social science and citizens' engagement in city making process;
- Sustainable, safe, resilient, socially inclusive, liveable and attractive neighbourhoods, towns and cities with reduced environmental footprint and enhanced well-being and quality of life for citizens;
- Participatory and multi-stakeholder policy and decision-making engaging local authorities, municipalities, business, civil society, knowledge institutions and citizens empowered with necessary knowledge, skills and tools to actively engage in sustainability and climate-neutrality transitions;
- Human-centred and cost-effective urban transformational transition pathways for Positive Energy Districts, accessible, connected urban mobility and green and circular cities accounting also for their inter-relations;
- Science and evidence based implementation of the European Green Deal, the Urban Agenda for the EU and other European, national, regional and local urban-relevant policies and strategies;
- Cities with enhanced technological, institutional, digital, nature-based and social innovation capacity able to play in full their critical role in providing solutions to global challenges and thus enabling the EU to achieve targets set out by the EU Green Deal and fulfil its commitments related to the UN Agenda 2030 for sustainability, the Urban Agenda for the EU, the Habitat III New Urban Agenda and the Paris Agreement.

<u>Scope:</u>

Cities are the home of complex, inter-dependent challenges related to resource depletion, climate change impacts, environmental degradation, water, air and soil pollution, health issues and social exclusion. Although they occupy about 3% of the Earth's land, they consume over 65% of the world energy, 75% of natural resource and account for more than 70% of the global CO2 emission. Today, more than 70% of EU citizens live in urban areas and it is expected that more than two thirds of the global population will be living in cities by 2030. Cities are also the engines of the European economy generating about 85% of the EU's GDP and hubs of technological and social innovation. As such, they are key players in shaping and providing solutions to these challenges and must urgently engage in unprecedented systemic transformational and bold transition towards sustainability and climate neutrality.

Important gaps in knowledge, evidence, innovation, technology, data, capacity and skills, lack of integrated approaches and deficit in applying research and innovation results to actions exist that prevent successful implementation of such transitions. Also institutional fragmentation, non-inclusive and non-participatory governance structures lead to a lack of shared vision, goal and direction regarding the transition process, incoherence in policies and strategies, uncoordinated planning and decision-making, ineffective measures and inefficient use of resources.

A co-funded partnership on Urban Transitions to a sustainable future is expected to make a considerable contribution towards filling up these gaps. By aligning, mobilising and leveraging EU, national and regional R&I agendas, programmes, priorities, activities and investments, including from the private sector and associating to the extent possible, the totality of EU Member States, it should create a pan-European critical mass and invest on challenge-driven R&I to underpin urban sustainability transitions. It should focus as priority on critical urban sectors such as Positive Energy Districts, accessible, connected urban mobility and urban greening and circularity, their inter-relations and interplay with cross-sectoral issues such as governance, digitisation, resilience, land use, infrastructures and public spaces for sustainable, liveable, inclusive and resilient cities. In doing so, the partnership must develop holistic, integrated, systemic and cross-sectorial approaches, foster co-creation processes involving all relevant urban stakeholders and actors, harnessing also the potential of social innovation and citizen's engagement, and deliver place-based portfolios of solutions, measures and tools whilst facilitating their replication, upscaling, up-taking and mainstreaming and market accessibility to increase the return to investments.

It should experiment and promote technological, nature-based, social, economic, cultural, planning and governance innovation and new governance, business and finance models.

In line with the European Commission's political vision of leaving no one behind, the partnership must harness the outreach potential provided by the presence of national funding agencies to mobilise cities, business, stakeholders, societal actors and research across Europe, including widening countries and small and medium size cities. This way it will serve the sustainability transition needs of the wide diversity and heterogeneity among cities across Europe regarding their socio-economic, technological, institutional, innovation and skills potential.

Emphasis must be given to place-based approaches and experimentation capitalizing on citizens' engagement, social innovation, user-led and citizen science, for shared ownership of solutions that are tailored to local specificities and thus ensure that envisaged transitions pathways are human-centred and just.

Major efforts must be invested in facilitating replication, upscaling and up-taking of solutions and accessibility to knowledge, portfolio of technologies, solutions, tools and practices. Activities promoting individual and collective behavioural changes, knowledge sharing, dialogues, peer-learning, awareness raising, communities and capacity building and skills enhancement must be pursued to enable urban actors, practitioners and society to become drivers for transformative transitions towards urban sustainability.

The European Partnership for 'Driving Urban Tradition to Sustainable Future' should be implemented through a series of joint calls for research and innovation projects and a comprehensive management and implementation plan promoting coordination, networking, training, demonstration and dissemination potentially structured along the following building blocks:

- Implementing joint calls for challenge-driven R&I;
- Setting-up of a multi-stakeholder community of practice to facilitate science-policy-business-society dialogues and sharing of experiences;
- Pursuing communication and dissemination measures to make R&I results accessible for all stakeholder groups;
- Preparation of methodologies, guidelines, references and tools for replication and mainstreaming of good "practice";
- Clustering of projects and synthesising of R&I results;
- Setting-up a knowledge hub, organising training activities, fostering ULLs and experience sharing on new approaches and solutions to support capacity building among urban actors;
- Addressing standardisation, certification or, wherever necessary, legislative issues;

- Setting-up rigorous monitoring to assess progress towards achieving the objectives of the Partnership and its contribution to relevant EU policies;
- Explore interfaces to public procurement and investment programmes by developing links with Urban Innovative Actions (UIA) under the Urban Agenda for the EU, European Urban Initiative (EUI) under cohesion policy, ESIF, private funds, etc. to support take-up and larger scale implementation of tested approaches and solutions.

Financial commitments and in-kind contributions are expected to be provided for the governance structure, the joint calls and other dedicated implementation actions and efforts for national coordination.

Whilst gradually opening up cooperation with new countries outside of Europe, international outreach, collaboration and cooperation with global and international cities and research funding networks should be pursued to align strategies and research agenda and promote scientific evidence and good practice for urban policy on international level.

To ensure coherence and complementarity of activities and leverage of knowledge and investment possibilities, the partnership is expected to establish a detailed action plan to foster close collaboration and synergies with other ongoing EU and nationally funded R&I actions, the mission on ”Climate-neutral and Smart Cities’ as well as other relevant Horizon Europe European Partnerships (e.g. Clean Energy Transitions; Built environment and construction, Rescuing biodiversity, Safe and Sustainable Food System, 2ZERO, Cooperative, Connected and Automated Mobility (CCAM), EIT Urban Mobility and Water4All. Proposers are expected to describe in details the way to implement such collaborations.

Proposals should pool the necessary financial resources from the participating national (or regional) research programmes with a view to implementing joints call for transnational proposals resulting in grants to third parties. Financial support provided by the participants to third parties is one of the primary activities of this action in order to be able to achieve its objectives. Therefore, the 60 000 EUR threshold provided for in Article 204 (a) of the Financial Regulation No 2018/1046 does not apply.

The Commission considers that proposals requesting a contribution from the EU of around EUR *[130 million]* would allow these challenges to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts. Up to one proposal will be funded. The EU contribution for this action will be implemented in annual instalments of around EUR *[18.5 million]*.

Up to one proposal will be funded.

Call conditions related to this topic are provided at the end of this call and in the General Annexes (here we will explain the general aspects, core of mandated organisations from MS, standards for call implementation, based on annual work programmes, flexibility to extend the scope of partners over time etc.)

Type of action: Programme Co-fund action (co-funded European Partnerships)

<u>Emerging breakthrough technologies and climate solutions</u>

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.

The development of breakthrough technologies (up to TRL 3) is not only an important enabler to reach climate goals but also a catalyst for technological leadership in next generation clean technologies. Therefore, the development of such breakthrough technologies has an economic rationale to keep Europe at the forefront of low-carbon technology development and enable the EU economy to benefit from this growing market. Under this topic area, the Commission wishes to create projects with some critical mass in research in the chosen areas of emerging technologies by bringing together different research groups with an outstanding track record in the research field, enabling cross-fertilisation and multi-disciplinary collaboration among research groups across the EU.

This area is not a duplication of Pillars I or III but focuses 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 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 EU economy;
- Development of technologies that directly filter, separate, concentrate or capture greenhouse gases, eventually from ambient air, and are therefore options to offset non avoidable greenhouse gas emissions in a climate-neutral Europe;
- Advancement of methane cracking technologies for making methane climate neutral;
- Establishment of novel inorganic photovoltaic absorbers using rapid development approach to lead to concepts that will improve the performance of photovoltaic technologies.

C5-D2-BT-01-2021: Emerging technologies for a climate neutral Europe

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 2,5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4 by the end of the project – see General Annex D.

Expected outcomes:

Project results are expected to contribute to [all/some] of the following expected outcomes:

- Development of high-risk/high return technologies to enable a transition to a net greenhouse gas neutral EU economy.
- Validation of emerging concept up to TRL 4
- To advance the knowledge and scientific proofs of the technological feasibility of its concept including the environmental, social and economic benefits
- To contribute towards establishing a solid dependable European innovation base

Scope:

The proposal is expected to address one of the following areas:

- Decarbonised, efficient, effective, and safe Transport
- Fuel cells
- Efficient electric motors/generators (power to X)
- Energy distribution
- Energy storage
- Negative emissions

The following areas are excluded from the scope as being covered under either partnerships or other calls:

- Material research
- Renewable energy technologies and renewable hydrogen production are addressed under C5-D3-RES-02-2021
- Batteries

The proposal should address the validation of its concept to TRL 4 through a robust research methodology and activities, establishing the technological feasibility of its concept including the environmental, social and economic benefits, and 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. Economic benefits could be for exemple technology cost reduction, job creations, new businesses and more efficient motors and generators.

Proposals including technologies providing the possibility of multi-fuel integration and/or the potential for the transversal intersectorial decarbonization are of great interest, together with those concepts targeting hard-to-decarbonize sectors and energy-intensive applications, such as road/rail/maritime transport or energy generation though thermal power generators. Additional relevant aspects of the technologies comprise the flexibility in terms of its scalability to different power/energy demands, the compatibility with local or distributed energy production layouts and the use of already available industrial processes and raw materials for easy TRL upgrading and final transfer to mass production.

In developing its concept the proposal is expected to address the following related aspects: lower environmental impact (e.g. on climate change, pollution and biodiversity), better resource efficiency (materials, geographical footprints, water, etc…) than current commercial technologies, 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. A Life Cycle approach is expected to be done with the relevant information that can be gathered at such TRL level.

C5-D2-BT-03-2021: Methane cracking to usable hydrogen and carbon

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 2 million and EUR 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Procedure	In order to ensure that a balanced portfolio of activities covering different emerging breakthrough technologies and climate solutions, the available budget will be firstly allocated to the proposal with the highest score, passing all thresholds, in each of the topics C5-D2-BT-03-2022 and C5-D2-BT-05-2022. In a second round, proposals will be selected for funding regardless of the topic and only according to the single ranking list of all four topic.
Technology or societal readiness level	Activities are expected to achieve TRL 5

<u>Expected Outcomes</u>:

Project results are expected to contribute to [all/some] of the following expected outcomes:

- Replacement of the unabated use of natural gas by climate-neutral (or negative, in case of cracking of biogenic methane) hydrogen
- Reduction of emissions by hard to decarbonise sectors, also considering the use of eventual by-products
- Faster reduction of GHG emissions by economies heavily relying on natural gas export or use (provided they reduce their upstream emissions).
- Production of economically usable by-product solid carbon (in tires, batteries, etc.)

<u>Scope</u>:

A potential breakthrough technology is represented by the development of processes allowing the use of available fossil and renewable methane to economically generate hydrogen without any release of CO2 or other GHGs (as in current processes). To be advantageous on a life cycle basis, however, this requires a higher efficiency than in current processes and that the used natural or renewable gas is supplied by a chain with low upstream leakage.

This requires the development of innovative methodologies to deliver high performance hydrogen production from methane by directly splitting the molecule in its components (hydrogen and solid carbon). Proposals shall demonstrate significant advances with respect to already achieved results in Europe and outside, delivering a minimum of 50% efficiency (i.e. energy from hydrogen recovery vs energy from original methane, for instance by reducing reaction temperatures and improving catalysts), and demonstrating the potential to achieve mass production and a competitive hydrogen cost and an improved climate performance with respect to current methane based, CO2 releasing hydrogen production methods including CCS. Due consideration should be given to the management of impurities in the source stream, and to the development of the economic potential of the carbon particles delivered by the specific technology which could have a valuable end-use (e.g. synthetic graphite or carbon black) or the development of side-streams of other carbon-rich chemical compounds (excluding uses which would re-release the carbon as CO2). Each project will dedicate part of its work programme to technology assessment to consider environmental, resource and economic aspects of the deployment of the technology).

For the purpose of technology monitoring and progress against the state-of-art, but also to identify how each of the projects contribute to reaching the targets and indicators set by the Commission's Communication "A Clean Planet for All", and the European Green Deal, all actions related to hydrogen and fuel cells funded under this topic shall report directly or indirectly on an annual basis in a secure online data collection platform[27] managed by the Clean Hydrogen Joint Undertaking. The reporting shall consist of filling in the template questionnaire(s) relevant to the project content (and the technology development and TRL). This should be integrated as specific annual deliverable in the grant agreement. The template questionnaires can be consulted online (http://www.fch.europa.eu/projects/knowledge-management), subject to modifications due to technology development and/or change in projects portfolio.

C5-D2-BT-05-2021: Technologies for non-CO2 greenhouse gases removal

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 2 million and EUR 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Procedure	In order to ensure that a balanced portfolio of activities covering different emerging breakthrough technologies and climate solutions, the available budget will be firstly allocated to the proposal with the highest score, passing all thresholds, in each of the topics C5-D2-BT-03-2022 and C5-D2-BT-05-2022. In a second round, proposals will be selected for funding regardless of the topic and only according to the single ranking list of all four topic.

<u>Expected Outcomes</u>: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Increase knowledge on the plausibility of removing non-CO_2 greenhouse gases from the atmosphere.
- Raise awareness on the effects of non-CO_2 greenhouse gases on earth warming.

[27] Currently being the tool TRUST (Technology Reporting Using Structured Templates)

- Develop technologies for addressing the effects of non-CO_2 greenhouse gas emissions.
- Investigate techno-economic aspects of technologies and physical properties of emissions striving to match both into market-ready solutions.

Scope:

Development of technologies for removing non-CO_2 greenhouse gases CH4, N2O and fluorinated gases.

Calls under the "breakthrough technology" area focus on concepts at low TRLs (e.g. below 3)

In the case of methane, the scope of possible applications is further constrained: Methane emissions stemming from the supply chain of fossil fuels are excluded, considering that such emissions are meant to be addressed through emission avoidance. Other emissions with a methane concentration higher than 1% are also excluded, considering that economic interests should drive their mitigation.

Technologies shall contribute to the capture, concentration, use and/or disposal of emissions, either from or at natural sources (if more concentrated) or in the atmosphere. Carbon dioxide may be considered, though only if any synergy can be found with processing it in combination with other greenhouse gas(es) which should be the prime focus. The state-of the art of technology development will be clearly presented in the proposal with global potential for emission reductions, cost figures and versatility and economic viability of use where appropriate.

Citizens and stakeholder engagement

The transition to climate-neutral economies and societies by 2050 is the defining challenge of this century. In response, the EU has launched the European Green Deal: it cements the continent's role as a front-runner in the fight against global warming and for the protection and restoration of its biodiversity and a healthier environment. The challenge is not just technical: it calls for wide-ranging societal transformations and the adaptation of lifestyles and behaviours. Engaging citizens and stakeholders is therefore critical for the success of the European Green Deal, as is making greater recourse to the Social Sciences and Humanities (SSH), alongside the Scientific, Technical, Engineering and Mathematical (STEM) disciplines.

The topics under his section target some still-existing, critical knowledge and capacity gaps in this field. They do not stand alone but aim to complement and support the broader integration ("mainstreaming") of citizen and stakeholder engagement as well as the social sciences and humanities (SSH) across the whole Horizon Europe programme map and particularly Cluster 5. Research and innovation needs covered include: making the transition to climate neutrality fairer and more just; arriving at more holistic, cross-sectoral approaches to the societal challenge of climate neutrality; and tackling barriers – as well as exploiting opportunities – germane to especially difficult contexts. EU intervention is required given the European-wide relevance of the issues addressed, to draw in and build on comparative perspectives and lessons-learned from across the continent, as well as to connect and scale up national-level efforts.

The objectives of the EU interventions under this heading can be summarised as follows:

- To render the transition to climate neutrality more just and equitable, by addressing its socioeconomic as well as socio-political and socio-cultural aspects;
- To facilitate and enable more cross-sectoral, multi-disciplinary work in climate, energy and mobility by strengthening social science and humanities (SSH) communities in these areas;
- To jumpstart the climate transition in especially difficult contexts via transition super-labs.

Expected impacts include:

- A better understanding of the societal implications of the climate transition, including its distributional repercussions;
- More effective policy interventions, co-created with target constituencies and building on high-quality policy advice;
- Greater societal support for transition policies and programs, based on greater and more consequential involvement of those most affected.

C5-D2-CC-01-2021: Fostering a just transition in Europe

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 4 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

Expected outcomes: Projects are expected to contribute to one or several of the following outcomes:

- A better understanding of the distributional repercussions of the transition to climate neutrality across sectors, social groups, countries, regions, cities, and in the labour market that will help implement the commitment to "leaving nobody behind";
- A better understanding of the trade-offs and synergies between climate action, climate-change impacts and equity and justice considerations, such as social inequality, as well as their interaction with other transformations that underpin the transition to climate neutrality;
- Addressing procedural justice concerns in the transition to carbon neutrality, via deeper and more consequential involvement of stakeholders from all parts of society in the transition process, for instance via co-design and co-production processes, citizen science, user-led innovation type activities, or upstream multi-stakeholder debates or mechanisms for citizen deliberation and engagement;
- New scientific evidence to inform EU, national and regional policies in designing inclusive, socially fair and economically viable transition plans and post-COVID recovery packages that take due care of the most affected regions, cities, sectors and parts of society, including vulnerable individuals and households;

- Increased societal and political acceptance for transition strategies and renewable energy projects based on greater involvement of those most affected, leading to better capacity for co-designing policy frameworks that enhance inclusiveness while minimising adverse distributional effects and inequalities;
- Improved insights into socio-economic and socio-political barriers that impede a just transition towards climate neutrality and identification of strategies to overcome these barriers on different temporal and spatial scales across Europe.

Scope:

Actions should enhance the understanding of the challenges of the “just transition” to climate-neutral and environmentally sustainable economies and societies, as envisaged in the European Green Deal and Next Generation EU. They should analyse various dimensions of inequality arising from climate change impacts, climate policies and transition pathways including their distributional implications associated with changes in GDP, industrial competitiveness and trade, employment and skills, taxation, incomes and wealth, vulnerabilities and human health, structure of sectors, business models and relative prices etc. Further equity aspects associated with climate change impacts and climate policy, such as differential vulnerabilities as well as intergenerational fairness or justice should also be studied, taking into consideration social and geographic circumstances and paying due attention to most vulnerable parts of the society (poor, elderly, children etc.). The gender dimension should also be explored. Research should integrate learnings from the COVID-19 pandemic in terms of the evolution of inequality in Europe and analyse potential implications for climate action and green recovery.

Actions should identify policy options and measures that combine climate and environmental benefits with intre- and intergenerational justice, e.g. by a reduction of poverty and inequality across different sectors of society, as well as within and between countries and regions. They should explore links between and combinations of climate-focused policies and social, taxation, employment and other relevant measures. Recommendations as to the most effective levers for enacting an inclusive, fair and just ecological transition should be formulated.

Beyond climate action, links to Sustainable Development Goals should be considered as many of them are centred on reducing poverty, inequality and meeting basic human needs.

Improving tools and methodologies for addressing intra- and intergenerational equity, equality and justice concerns in the context of the transition to climate neutrality is part of the action’s scope, but should take into account the work by projects in other parts of the work programme, notably those addressing the improvement of Integrated Assessment Models under Destination 1 on Climate Science. Research should comprise a strong empirical component, including field experiments, and meaningfully involve stakeholders to collect evidence, test proposals and discuss relevant issues.

Actions are expected to mobilise and build on the knowledge from across a broad range of social sciences (including behavioural science, political science, sociology, economics, law etc.) and humanities and involve all parts of the quadruple helix (public bodies, industry/SMEs, academia/research, citizens/civil society) in a meaningful transdisciplinary manner and across activities[28]. Synergies with other topics in Cluster 5 and especially the topic C5-D2-CC-03-2021 on Transition Super-Labs should be explored, given that equity and fairness considerations will play a very important role in that context, too.

C5-D2-CC-02-2021: Strengthening Social Sciences and Humanities (SSH) research communities in climate, energy and mobility disciplines

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 2 and 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Research and innovation communities focusing on Social Science and Humanities (SSH) approaches to climate, energy and mobility as well as on citizen engagement and empowerment are less fragmented and better networked across Europe, including with respect to Eastern and Southern Europe;
- A targeted strategy for intensifying collaboration between Scientific, Technical, Engineering and Mathematical (STEM) and Social Science and Humanities (SSH) research and innovation communities has led to more and more in-depth interdisciplinary work;
- Dedicated outreach and engagement activities have produced strong links to principal stakeholder communities, including policymakers at various levels, the private sector, academia, civil society, and citizens at large;
- Project activities have lowered social and behavioural barriers and contributed to greater citizen engagement in the context of the SET-Plan, Horizon Europe Missions, Horizon Europe Partnerships, or other research and innovation actions supported by the EU's framework programme, in collaboration with or building on other EU-funded projects in these areas;
- Policy advice to policymakers, including at EU and other levels, is actionable, specific and based on the latest research, including work prepared in the context of this project;

Scope:

Confronting the threat of global warming and transitioning to carbon neutrality by mid-century requires research and innovation in a number of distinct but interconnected areas, notably in climate science, energy, and mobility. Along with technological innovations, successful solutions need to factor in changing lifestyles, forms of behaviour, value structures,

[28] Projects focused on Responsible Research and Innovation (RRI) may be particularly relevant in this regard; a large number of these can be found in the Science with and for Society part of Horizon 2020: https://op.europa.eu/s/oeby.

governance arrangements at institutional or corporate levels, as well as forms of social organisation. This calls for concerted, multi-disciplinary approaches that are rooted in a variety of academic disciplines but also draw in and engage policymakers at various levels, the private sector, civil society and citizens at large.

To develop and enact such approaches, more extensive networks connecting relevant communities of researchers and practitioners are required, to facilitate and enable deeper and more consequential forms of collaboration. In particular, Scientific, Technical, Engineering and Mathematical (STEM) communities in climate science, energy and climate need to work more closely with those in the Social Sciences and Humanities (SSH) disciplines, ensuring adequate outreach especially to the eastern and southern parts of Europe. At the same time, methods and mechanisms for lowering social and behavioural barriers and engaging citizens and stakeholders need further refinement, more extensive application and improvement via co-creation and co-production processes, and greater dissemination. Focus areas requiring specific attention include prosumers, renewable energy and mobility communities, , resource efficiency and the circular economy, as well as digital platforms and technologies.

Developing novel, multi-disciplinary perspectives, strengthening SSH research communities while encouraging collaboration with the STEM disciplines, and nurturing linkages with stakeholder communities, civil society and citizens at large are important preconditions for providing targeted, high-quality advice on how to confront the manifold challenges surrounding the transition to climate neutrality. Policymakers at EU and other levels have obvious need for such advice, in delivering the European Green Deal and other high-profile policy initiatives.

Projects under this topic are expected to work towards these goals, while also producing novel research and concrete applications that can inform policymaking, notably at EU-level including with respect to the European Green Deal.

C5-D2-CC-03-2021: Accelerating the climate transition in difficult contexts: transition super-labs (pilot)

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 2 and 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- A mapping exercise has identified which settings across Europe – such as non-sustainable business complexes, mining regions or polluted metropolitan areas – would benefit the most from the transition super-labs approach, and which settings could serve to demonstrate the utility of this approach more generally.
- In-depth feasibility studies have been carried out in a select number of these settings, yielding programmatic, actionable blueprints with a view of launching actual transition super-labs at a subsequent stage;

- Enabling coalitions for the practical delivery of transition super-labs have been assembled, with the participation of policymakers at local, regional and other levels, business, finance, civil society organisations, individual citizens, as well as academia;
- A detailed program outline for the practical delivery of a number of transition super-labs in several contexts across Europe, comprising at least three EU Member States and/or Associated Countries, has been prepared, including an assessment of the contribution of different funding instruments (European, national regional and private funds);

Scope:

First suggested by the High-Level Panel of the European Decarbonisation Pathways Initiative, Transition Super Labs are a novel way of linking research and innovation with policy. They are particularly relevant for challenges that defy purely technocratic solutions and require fundamental transformations in economies and societies, including lifestyle and behavioural changes. Anchored in the EU's research and innovation framework program, they provide ample room for co-creation with Member States, stakeholders and citizens.

Transition Super Labs are real-life laboratories where rapid decarbonisation is conceptualised, implemented, monitored and revised in an integrated way. Similar to "living labs" but operating at a much larger scale, they spur the transformation of whole entities – such as non-sustainable business complexes, mining regions and polluted metropolitan areas – in an economically, socially and environmentally sustainable manner.

Designed as flagship demonstrators, Transition Super Labs involve a broad range of actors – businesses and industry, different levels of government, academia, civil society, citizens at large – working closely with communities and regions directly affected by climate change. They provide an ideal complement to mission-driven innovation in that they test systemic innovations at scale and in real-world conditions. Confronting concepts and ideas with technical, environmental and socioeconomic realities, they identify and help to overcome critical bottlenecks and cultural resistance while avoiding false ecological trade-offs.

This topic supports a set of pilot activities designed to prepare the launch of several fully-fledged transition super-labs at a subsequent stage.

C5-D2-CC-04-2021: Fostering cooperation between Horizon Europe cluster 5 National Contact Points (NCPs)

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 2 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action
Eligibility	Applicants must be Horizon Europe national support structures (e.g. NCP) responsible for clusyer 5 and officially nominated to the Commission, from a Member State or Associated Country or any third country associated to Horizon Europe. Only in case and as long as Horizon Europe structures would not yet be officially nominated, national support structures responsible for cluster 5 nominated for Horizon 2020 would be eligible.

Procedure	The granting authority can fund a maximum of one project.

Expected Outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Improved professionalisation/skills of NCPs across Europe, helping to simplify access to Horizon Europe calls, lowering the entry barriers for newcomers, and raising the average quality of proposals submitted.
- Harmonised and improved trans-national cooperation between NCPs.
- Increase cooperation with Enterprise Europe Network
- Connection with horizontal NCP Networks activities

Scope:

- Proposals should aim to facilitate trans-national co-operation between National Contact Points (NCPs) with a view to identifying and sharing good practices and raising the general standard of support to programme applicants.
- Special attention should be given to enhancing the competence of NCPs, including helping less experienced NCPs rapidly acquire the know-how built up in other countries.
- The consortium should have a good representation of experienced and less experienced NCPs and reflect the diversity of the areas covered under cluster 5.
- The project should establish close cooperation and exploit synergies with other relevant NCP support structures.
- Proposal should aim to facilitate trans-cluster cooperation in the areas covered by Pillar 2, with a view to identifying synergies, to make possible to share good practices and tools. A close coordination and cooperation will be essential to achieve the objectives and impact of the NCPs networks.
- The activities of this topic should be built on the knowledge and tools generated by the NCP networks developed under H2020 program.
- The proposal should cover the whole duration of Horizon Europe.

Destination 3 – Sustainable, secure and competitive energy supply -2021-2024

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 CO2 emission abatement option that holds great potential and R&I actions will accelerate the development of CCUS in electricity generation and industry applications.

Expected impacts at Destination-level and their link to expected impacts of the Strategic Plan

Activities under this Destination should set out a credible pathway for contributing to the following **Destination-level expected impacts** (more detailed impacts for each thematic area are elaborated in the introductory text of the thematic area):

a) **Foster 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.

b) 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.

c) **Accelerate the development of CCUS** as a CO2 emission mitigation option in electricity generation and industry applications (including also conversion of CO2 to products).

These Destination-level impacts will directly support the **Strategic Plan's expected impact** of *"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"*.

Fostering the European global leadership in affordable, secure and sustainable renewable energy technologies

Both the EU long-term climate strategy and the European Green Deal highlight the pivotal role of renewable energies in the future clean European energy system and the achievement of its zero-emission target. Renewable energy technologies provide also major opportunities to replace or substitute carbon from fossil origin in other economic sectors such as heating/cooling, transportation, agriculture and industry. Their large scale and decentralised deployment is expected to create more jobs than the fossil fuel equivalent. Renewable energy technologies are the baseline on which to build a sustainable European and global climate-neutral future. A strong global European leadership in renewable energy technologies, coupled with circularity and sustainability, will pave the way to increase energy security and reliability in time of crisis, as can be seen today during the COVID-19 crisis, and beyond. It will also lead to achieve the objectives of the European Green Deal, as well as to sustain the economic recovery and growth in the long term, while ensuring a sustainable future for European citizens.

To contribute to this impact, it is imperative to enhance affordability, security and sustainability of renewable energy technologies and therefore efficiency improvements for the more established renewable energy technologies (such as wind energy, photovoltaics or bioenergy) are addressed, while further diversification of the technological portfolio is also essential to support the clean energy transition. Furthermore, advanced renewable fuels, including synthetic and sustainable advanced biofuels, are also needed to provide long-term carbon-neutral solutions for the transport and energy-intensive industrial sectors, in particular for applications where direct electrification is not a technically and cost efficient option and fuels with high energy density are required to reduce the fossil carbon and environmental footprint of these sectors.

Several topics focus here mainly on creating and enabling energy supply from renewable energy sources along the entire technological cycle of innovation. These topics are complemented with topics for market uptake of the technologies and with topics for overarching sustainability issues, thus addressing the feasibility of these solutions for a clean, secure and competitive energy supply.

In line with the “do not harm” principle for the environment, 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. In particular, 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 parts of the WP. Other topics look at making the renewable energy supply more flexible and integrating it within given industrial processes, sectors or applications. The focus is on developing flexible energy supply technologies and delivering technological solutions to the energy integration challenge based on renewables.

As stated in the Horizon Europe Strategic Plan, international cooperation is crucial to ensure a wide development of clean energy systems and in particular renewable energy. While all the topics are open to international partners, the focus in this area of the work programme is to develop further the African Union-European Union Research and Innovation Partnership on Climate Change and Sustainable Energy (CCSE) and to continue research and innovation cooperation with neighbourhood countries and with strategic and like-minded partners in the Americas and Asia. In addition, support to Mission Innovation is the focus in some topics.

The contribution of social science and humanity disciplines is implemented as needed in the topics in order to produce a meaningful and significant outcome enhancing the societal impact of the related research activities in the renewable energy technologies. Specific examples are illustrated in topics C5-D3-RES-18-2021 and C5-D3-RES-19-2021.

The **expected impacts** for this area contributing to the destination expected impact are:

a) Developing disruptive renewable energy and renewable fuel technologies and systems for existing and new applications from early stage technology readiness so that they are available in 2050 in order to accelerate the replacement of fossil-based energy technologies.

   The main topics addressing this area impact are: C5-D3-RES-02-2021, C5-D3-RES-03-2021

b) Reducing cost and improving efficiency of renewable energy and renewable fuel technologies and their value chains.

   The related topics are:

   - Wind: C5-D3-RES-04-2021, C5-D3-RES-05-2021, C5-D3-RES-32-2022
   - PV: C5-D3-RES-06-2021, C5-D3-RES-07-2021, C5-D3-RES-33-2022
   - Bioenergy : C5-D3-RES-08-2021, C5-D3-RES-34-2022
   - Biofuels: C5-D3-RES-11-2021, C5-D3-RES-35-2022
   - Renewable fuels C5-D3-RES-30-2022, C5-D3-RES-61-2022
   - Geothermal : C5-D3-RES-37-2022
   - Ocean Energy : C5-D3-RES-14-2021
   - CSP : C5-D3-RES-12-2021
   - Hydropower : C5-D3-RES-15-2021, C5-D3-RES-40-2022

c) Scaling up renewable energy and renewable fuel technologies to demonstration size to achieve technology de-risking as a necessary step before commercial exploitation, thus facilitating achievement of net zero greenhouse gas emissions by 2050

The related topics are:

- Wind: C5-D3-RES-16-2021, C5-D3-RES-41-2022
- PV: C5-D3-RES-17-2021, C5-D3-RES-43-2022, C5-D3-RES-44-2022, C5-D3-RES-67-2022
- Bioenergy : C5-D3-RES-18-2021, C5-D3-RES-46-2022
- Biofuels: C5-D3-RES-19-2021, C5-D3-RES-20-2021, C5-D3-RES-47-2022
- Geothermal : C5-D3-RES-49-2022
- Ocean Energy : C5-D3-RES-23-2021, C5-D3-RES-50-2022
- CSP : C5-D3-RES-21-2022

d) Developing renewable energy and renewable fuel-based solutions, combining variable with dispatchable technologies and integrating them efficiently within the existing energy system infrastructure or embedding renewable energy and renewable fuel generation technologies in energy consuming sectors such as transport, agriculture, chemical, manufacturing and energy-intensive industrial sectors

   The related topics are: C5-D3-RES-02-2021, C5-D3-RES-62-2022, C5-D3-RES-63-2022, C5-D3-RES-65-2022, C5-D3-RES-68-2022

e) Reinforcing the EU scientific basis through international collaboration while increasing the potential to export EU renewable energy technologies to global developing markets and contributing to the Joint Africa-EU Strategy through the development of international cooperation with Africa in renewable energy technologies and renewable fuels and enhancing collaboration with Mission Innovation countries

The related topics are: C5-D3-RES-01-2021, C5-D3-RES-27-2022, C5-D3-RES-28-2022, C5-D3-RES-29-2022

f) Enhancing the sustainability of renewable energy and renewable fuels value chains by addressing social, economic and environmental aspects in full, thus ensuring the European Green Deal priorities are met

The related topic is: C5-D3-RES-26-2021

g) Developing market uptake strategies and measures for renewable energy and renewable fuel technologies to ensure their market penetration

The related topic is: C5-D3-RES-56-2021

C5-D3-RES-01-2021: AU-EU Water Energy Food Nexus

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 2,5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4 by the end of the project – see General Annex D.
Eligibility	The following exception applies: In addition to the conditions described in General Annex B, three partners from three different African countries must be part of the consortium.

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

- Contribute to and reinforce the AU-EU HLPD CCSE Partnership
- Advance knowledge and scientific modelling of the water energy food nexus including the environmental, social and economic trade-offs
- Contribute to increase clean energy generation in the African energy systems
- Create African experts and expertise in this area
- Contribute towards establishing an evidence base for decision making
- Improve governance to advance knowledge and scientific modelling of the water energy food nexus including the environmental, social and economic trade-offs (governance aspects should be included since they are under-represented in the current research works)

Scope:

The topic is contributing to the activities of the AU-EU High Level Policy Dialog (HLPD) Climate Change and Sustainable Energy (CCSE) partnership. Climate changes and increase usage of water in all economic activities create more stresses on water use for energy generation. Energy generation covers in this context energy from renewable sources and energy vectors such as electricity, heat and fuels. Therefore the needs for African countries of having their own dedicated models to simulate and estimate the stresses on the water-energy nexus are crucial for their policy decision and energy planning. International agreement and trade issues can be considered in the model. Most of the current models are based on developed country standard and usage.

The proposal should then develop and test models for decision makers and planners to implement energy infrastructures and energy supply in Africa which safeguard a systemic approach to the water-energy food nexus. These models can be based on existing reliable source codes and models. The test should be made on the case of an existing African water basin. Participation of societal stakeholders is considered important

Actions should promote the highest standards of transparency in model adoption, going beyond documentation and extending to aspects such as assumptions, architecture, code and data. The outcome of the project should be widely disseminated and the source code of the model should be open access to stimulate future development. To ensure future uses, African experts in water-energy nexus and in model development should be full partners in the project. The project should identify further local training needs.

The project should also link with existing European activities to create synergies and cross-fertilisation. The project should participate in the activities of the HLPD CCSE partnership.

C5-D3-RES-02-2021: Next generation of renewable energy technologies

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 3-4 by the end of the project – see General Annex D.

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

- Develop breakthrough and game changing technologies enabling a faster transition to a net-zero greenhouse gas emissions EU economy
- Validate emerging concept up to TRL 3 or 4
- Advance the knowledge and scientific proof of concept of technological feasibility including the environmental, social and economic benefits
- Contribute towards establishing a solid 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 are excluded from the scope as being covered under either partnerships or other calls:

- Pure material research
- Conventional hydrogen production and fuel cells
- Batteries

However the production of renewable hydrogen directly from renewable energy sources is within the scope of the topic.

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 including the environmental, social and economic benefits, 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,

The project should also document the research process thoroughly - methods, data, results - to ensure that future research and deployment builds on lessons from positive and negative attempts made.

C5-D3-RES-03-2021: Hybrid catalytic conversion of renewable energy to carbon-neutral fuels

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 3-4 by the end of the project – see General Annex D.

Expected outcomes: Carbon-neutral fuels respond to longer-term future demands for high energy density carriers in sectors relying on liquid fuels and their catalytic synthesis should become more efficient and technically sound. Fostering catalytic synthesis of performing carbon-neutral fuels will contribute to advance the EU scientific basis, leadership and global role in the area of renewable fuels by moving forward the supra-national actors, to provide breakthrough solutions based on such fuels towards a fossil-free economy and to reinforce the EU scientific basis and potential to export EU renewable fuel technologies through international collaboration.

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

- Foster availability of synergetic catalytic systems for carbon-neutral renewable fuels.
- Improve performance of carbon-neutral renewable fuels and EU competitiveness.
- Accelerate development of performing carbon-neutral renewable fuels.

Scope:

Proposals will develop hybrid catalytic conversion processes, combining chemical, electrochemical, biological, biochemical and thermochemical catalytic processes to convert renewable energy to carbon-neutral renewable fuels of biological or non-biological origin, and which respond to longer-term future demands for high energy density carriers in sectors relying on liquid fuels. The development and combination of novel catalysts and linked lab-scale components and/or systems which improve significantly the performance regarding conversion efficiency for best atomic economy and specific marginal cost reduction should be addressed. Development of catalysts and/or systems with dual function, e.g. catalyst/sorbent may be included. Combination of at least two different catalysts types into a single multicatalytic material as appropriate should be addressed. Improvements as regards the conversion of a broader variety of molecules from the same feedstock and the broader application of hybrid catalytic systems in up-scaled processes should be examined. Maximizing GHG emissions abatement in the conversion process should be aimed. International cooperation is encouraged. Combination of H2 production by electrolysis and its separate use for catalytic conversion of CO2 is excluded. Production of H2 as a final product is also excluded.

C5-D3-RES-04-2021: Physics and aerodynamics of atmospheric flow of wind for power production

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of up to EUR 9 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

Expected outcomes:

As wind turbines grow bigger and taller, the blade tips are increasing more affected by turbulent atmospheric flow features, while airborne wind energy systems operate at even higher altitudes. This zone of the atmosphere currently lays between the current numeric models at the microscale and the mesoscale. Further, the data integration of the models of these different altitudes is still scarce. Thus, there is a need for an improved understanding of atmospheric flow physics, particularly regarding wind power production forecasting. It is expected that better predictions of wind patterns will:

- Support improved wind farm design, location choice, distribution and operation thus bridging the gap between small-scale controlled experiments and full-scale deployment;
- Enhance system reliability and power production;
- Decrease economic uncertainties related to farm design and power production;
- Lead to the development of numerical models capable of accurately forecasting high wind flow and power production. It will also improve wakes modelling and the integration of models with real condition wind farm data;
- Use open access of Big Data storage and usage for the parameterization and feedback of the numeric models.

Scope:

The proposal should:

- Develop an open access knowledge hub for experimental data, based on the principles of open data sharing. Collaborations with Copernicus are strongly encouraged in this context;
- Develop and validate numeric models to accurately forecast wind flow in low, medium and high altitudes in onshore and offshore scenarions. These models must address how external factors and different climate conditions affect power production and loads on the different neighbouring systems;
- Integrate these different developments (knowledge hub and forecasting models) into a tool able to be readily absorbed by the sector. This integrated approach should be applicable to different wind energy conversion technologies: onshore wind, both fixed bottom and floating offshore wind, and high altitude wind systems;
- Validate and promote how such tools could be used to improve the design and deployment of wind farms, through case studies;
- Address and test how such integrated tools can be used for design development of wind technology components (blades, towers, substructures, kites), in particular on the issue of energy efficiency and material durability.

Further indirect impacts on decreased material usage, system efficiency, and social issues should also be made explicit. In order to optimise impact and enhance synergies, cooperation with projects from the Horizon 2020 LC-SC3-RES-31-2020 call is particularly encouraged.

C5-D3-RES-05-2021: Wind energy in the natural and social environment

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

Expected outcomes:

Renewable energy sources will be evermore present in the lives of European citizens, thus a harmonious co-existence is essential. Wind turbines are particularly susceptible to the NIMBY effect (Not In My BackYard), and hence it is facing opposition despite being a high-potential clean energy source. In order to achieve the European goals on climate neutrality, dedicated actions in this context are needed to ensure that large turbines retain a low environmental impact and gain more popular support. A particular focal point should be how to best engage with different communities to identify actions toward the co-existence goal.

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

- Develop and promote the use of modelling tools and holistic assessment metrics for realistic in-depth analysis of cumulative impacts of wind installations on the environment and local communities;
- Develop guidelines to enhance energy citizenship [29]of (onshore and offshore) wind energy and farms, promoting a harmonious co-existence between the local population, other sectors (e.g. fishing communities, tourism) and the wind farms;
- Realise outreach activities to promote scial awareness and engagement on wind energy, and develop guidelines for participatory processes in wind farm development to reach interactive and mutually value-enhancing outcomes;
- Facilitate both the identification of future areas for deployment, notably of offshore wind farms, and the consenting process.

Scope:

The proposal should:

- Develop and promote the use of validated models and guidelines as a tool for enhanced societal engagement. Further, it should also demonstrate how participatory processes can enhance value creation and achieve higher social acceptability of wind energy;
- Assess through validated models how wind turbines impact the local environment (noise, impact on soil or sea beds, visual effect, effects on animal life). In addition, it should also assess if applicable, how offshore wind turbines (and fixed or floating substructures) impact the local marine environment (currents, waves, upwelling, and sediment transport). Finally, it should help to identify the best areas for deployment and to develop new designs to address potential impacts;

[29] Creating energy citizenship through material participation

- Develop a forum where regulators, industry, and local communities can exchange information and provide input to one another. Further, it should also identify the effect that the implemented models have on promoting wind energy;
- Address how the impact of different wind energy innovations and applications (onshore, offshore, floating, and airborne) is seen by the general public and the local actors.

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.

C5-D3-RES-06-2021: Novel tandem high efficiency Photovoltaic technologies targeting low cost production with earth abundant materials

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Demonstrate the potential of tandem solar technologies for efficiencies beyond the single-junction Shockley–Queisser limit (~29%).
- Increase the potential of tandem technologies with earth abundant materials for mass production at low manufacturing cost.
- Minimise the impact of PV on landscape and environment by increasing its energy yield/m2.
- Contribute towards establishing a solid European innovation base and a competitive, continuous and coherent PV value chain.

Scope:

Tandem-junction cell architectures present a path towards higher module efficiencies over single-junction designs because of the ability to split the solar spectrum into multiple bands that can be more efficiently converted by separate devices (monolithically integrated and bonded/mechanically stacked). This enables surpassing the limiting efficiency of single-junction Si (~29%), which has neared its theoretical limit. As module costs drop, balance-of-systems costs dominate the cost of PV installations, and gains in efficiency could influence more the overall system costs, the energy yield/m2 and hence the land use or the integration potential of the technology. The aim is to develop tandem cells and modules that will reach efficiencies >30%, offer the same lifetime and degradation rate as standard crystalline panels and only marginally higher cost, creating thus a viable economic pathway for commercialisation of these technologies.

The proposal should address all of the following:

- Develop novel concepts that optimise PV cell and module architecture, increase durability, decrease losses and target very high efficiencies, taking also into consideration specific applications.
- Employ simple, scalable and low cost processing techniques; deliver proof-of-concept for equipment development to support novel layer deposition.
- Perform device/module real –life (under actual outdoor operating conditions) characterisation for reliability and energy yield assessment.
- Perform a life cycle analysis to bring evidence of the lower environmental impact, better resource efficiency than current commercial PV technologies, and circularity potential.

C5-D3-RES-07-2021: Stable, high performance Perovskite Photovoltaics

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Increase the efficiency and stability and minimise the environmental impact of Perovskite PV.
- Enlarge with bandgap tuneable perovskites and corresponding device architectures the integration and application possibilities of PV technology.
- Increase the potential for commercialisation of perovskite PV, creating a competitive technological know-how for the European PV industrial base.

<u>Scope</u>:

Perovskite PV are welcomed as an emerging technology for solar energy conversion, as today they afford high power conversion efficiency (PCE), higher than 25%. At the same time, perovskite semiconductors are based on abundant and low-cost starting materials and can be processed using simple and economic methods. The tuneable bandgap of the perovskite materials opens a lot of applications in a wide range of optoelectronic devices, even beyond solar cells. To ensure however economic feasibility and competitive levelized cost of electricity, the technology must offer long-term stability alongside high power conversion efficiency to match the reliability of silicon-wafer-based modules (the lifetime expectation for a PV module in a power plant is 20–25 years). At present, the long-term stability of lead halide perovskite modules does not meet this target and improvements are hampered by a lack of understanding of the cell and module failure modes. In addition to the intrinsic cell stability issues of perovskite PV, the usage of lead and scaling-up are the main challenges towards bringing perovskite technologies to the market.

The proposal should address all of the following:

- Research and resolve the degradation issues/mechanisms encountered from material to module and produce stable and highly efficient perovskite PV architectures/modules by optimizing the constituent materials, the architecture of the cell, the interfaces, the interconnections between cells, the environment conditions during the fabrication steps of cells and modules, the encapsulation of cells and modules, etc.
- Propose new device concepts and new materials (improved lead-halide perovskites or Pb-free perovskite analogues) to deal with any toxicity issues.
- Develop adequate stability assessment methods/measurements. Propose device/module real –life (under actual outdoor operating conditions) characterisation for reliability and energy yield assessment.
- Identify environmental hotspots and how to address them. Perform a life cycle analysis (including decommissioning and disposal) to bring evidence of the low environmental impact, better resource efficiency than current commercial PV technologies, and circularity potential.

C5-D3-RES-08-2021: Cost-effective micro-CHP and hybrid heating systems

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Increased technical performance, robustness, sustainability and penetration of renewables at household level
- Increase technology leadership and competitiveness of EU industry
- Increased production share of renewables at consumer level
- Assessment of socioeconomic and environmental sustainability of renewables based energy systems at household level

Scope:

Develop new technologies for biomass micro-CHP systems, including e.g. high efficiency supercritical CHP systems with embedded integration of other renewables into hybrid heating systems for maximizing the overall share of renewables at household and/or multifamily level and emission reduction.

Improve the integration of compatible renewable technologies in household and/or multifamily generators of heat and power making them attractive by addressing technological bottlenecks, efficiency, cost-effectiveness and socio-economic as well as environmental sustainability.

C5-D3-RES-11-2021: Carbon-negative sustainable biofuel production

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex D.

<u>Expected outcomes</u>: Reusing biogenic effluent gases from biofuel production in the same process, increases the biomass conversion efficiency and sustainability potential and the overall resource and energy efficiency of the biomass utilization. Improving such integration will contribute to advance the EU leadership and global role in the area of sustainable biofuels, increase the biofuel technology competitiveness and acceptance and allow high penetration of biofuels in the energy system, in particular for hard to electrify sectors, while supporting the EU goals for climate change mitigation, energy independence and economic growth.

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

- Increase bioenergy efficiency and sustainability.
- Increase sustainable biomass resource utilization.
- Generate negative emissions from biofuel production.

<u>Scope</u>:

Proposals should develop cost-effective solutions to minimize carbon waste in sustainable biofuel production processes by incorporating biological and/or chemical capture of the biogenic effluent gas emissions from the process and use it as appropriate either for separate in-situ downstream synthesis of renewable fuels of biological origin, or integrate it in the sustainable biofuel production through recycling. Synergies with renewable hydrogen production should be developed by incorporating it as appropriate in the sustainable biofuel production to compensate for additional needs in hydrogen, increase overall biomass conversion efficiency, minimize the biogenic carbon waste and reduce the fossil carbon footprint of the biofuel production. The overall GHG emissions should be assessed on the basis of a Life Cycle Analysis for proving negative GHG emissions and higher sustainability potential of biofuel production when reusing biogenic effluent gases in-situ, along with addressing socioeconomic aspects.

C5-D3-RES-12-2021: Novel approaches to concentrated solar power (CSP)

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of approximately EUR 2,5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex D.

<u>Expected Outcomes</u>:

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

- Future, higher-efficiency concentrated solar power (CSP) plants
- Reduced levelized cost of electricity of future CSP plants
- Significant performance regarding start-up, shutdown and load variation of future CSP plants
- Improved environmental profile of future CSP plants

<u>Scope</u>:

Support will be given to novel solutions that use concentrating solar thermal energy to generate power.

In terms of power dispatchability, the novel solutions will have to ensure a performance at least equivalent to current commercial installations.

Solutions that cogenerate power and heat are also in the scope. Moreover, solutions that support the concentrating solar thermal technology with photovoltaic technology are also in the scope.

Projects shall assess the sustainability of the proposed solutions in environmental and socio-economic terms. Applicants are encouraged to consider a ‘circularity by design’ approach.

C5-D3-RES-14-2021: Innovative foundations, floating substructures and connection systems for ocean energy devices and offshore floating PV

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of approximately EUR 3.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex D.

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

- Improve the overall life time, reliability and maintainability of marine substructures and connection systems for ocean energy devices and offshore floating PV to reduce degradation and failure rates and thus the risk of investment.
- Better understanding of the device's real life performance allowing a safe reduction in the over-engineering of devices' specifications.
- Contribute to LCOE reduction in line with the SET-Plan targets (actions should clearly state estimated LCOE at project start and end, using a recognised calculation methodology).
- Contribute to the objectives of the Mission: healthy oceans, seas, coastal and inland waters.

Scope:

The action should:

- Test and validate the potential benefits of new circular materials in offshore floating PV and ocean energy substructures, foundations and if relevant mooring and anchoring systems whilst ensuring structural integrity and durability considering very high wind (speed >25 m/s), current (>1.2 m/s) and wave (height >14 m) loads and corrosion on all elements of the ocean energy systems.
- Test and validate new prototype components and materials used in offshore floating PV and ocean energy devices and verify that they are compatible with and resistant to the marine environment**.**
- Research material properties and behaviour in combination with the use of improved predictive computational modelling tools.
- Research, develop and validate improved predictive computational modelling tools for material properties. The use of existing test facilities and related research infrastructures for resource assessment & environmental loading on the structures should be considered.

C5-D3-RES-15-2021: Development of hydropower equipment for hidden hydropower

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Advance the EU scientific basis, leadership and global role in the area of sustainable hydropower while creating evidence for policy making
- Create additional sustainable hydropower capacity to the existing fleet, maintain and advance European technological competitiveness in the sector, thus supporting the EU goals for climate protection, energy independence and economic growth
- Enhance sustainability of added hydropower capacities by addressing social, economic and environmental aspects and by promoting prosumer renewable energy in cities and communities

Scope: Development of hydropower equipment for hidden hydropower by developing novel technologies which allow for increased techno-economic feasible and sustainable hydropower production in unpowered hydraulic systems with low head and/or small reservoir or water body size and/or impaired water quality (e.g. saltwater), that may also involve prosumer solutions.

C5-D3-RES-16-2021: Innovation on floating wind energy deployment optimized for deep waters and different sea basins (Mediterranean, Black Sea, Baltic Sea, Atlantic...)

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 16 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.
Award criteria	In order to ensure a balanced portfolio, priority will be given to high ranking proposals demonstrating at different sea basins, provided they meet the thresholds.

Expected outcomes:

Floating offshore wind has the potential to unleash a new European industrial sector able to deliver clean and sustainable energy. Building from European technological and industrial know-how and harnessing the natural resources of the different sea basins around the European Union, namely the Mediterranean, the Black Sea, the Baltic Sea and the Atlantic, there is an opportunity to leverage these conditions into technological leadership, while supporting the goal of climate neutrality.

In this context, project results are expected to contribute to all of the following expected outcomes:

- Development or significant improvement of designs that reduce CAPEX and OPEX;
- Deployment of advanced full-scale floating wind turbines prototypes in operational environment;
- Allow development of cost-efficient scalable solutions supporting exploitation the renewable energy offshore potential in challenging conditions, while building from new designs of floating structures and auxiliary equipment;

- Demonstration of offshore technologies in operational environment;
- Contribute to LCOE reduction in line with the SET Plan targets (actions should clearly state estimated LCOE at project start and end).

Scope:

The proposal should demonstrate in one of the possible sea basins[30]. Further, the proposal should:

- Demonstrate how innovations (materials, technologies, designs,…) on floating wind turbines, substructures, dynamic cables, control systems, and moorings positively affects production;
- Demonstrate in real use scenario the improvements that the identified solutions contribute in terms of life expectancy, cost reductions, maintenance of a floating offshore wind installation;
- Demonstrate how the proposed innovations positively increase rate of deployment of offshore wind in deep seas, reducing capital, operational and maintenance costs and present an industrial roadmap for a floating energy industrial sector, with focus on mass production;
- Demonstrate a modular design suited to large-scale deployment in various environments, with special focus on industrial mass production;
- Ensure minimal environmental impact of these innovations, and address how Maritime Spatial Planning can be used to facilitate the identification of suitable locations for floating wind platforms.

The proposal has to include a clear go/no go moment ahead of entering the deployment phase. Before this go/no-go moment, the project will have to deliver the detailed engineering plans, a complete business and implementation plan and all needed permits for the deployment of the project. The proposal should clearly demonstrate a proposed pathway to obtaining necessary permits for the demonstration actions and allow for appropriate timelines to achieve these. The proposal should also 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.

C5-D3-RES-17-2021: Demonstration pilot lines for alternative and innovative PV technologies (novel c-Si tandem, thin film tandem, bifacial, CPV, etc.)

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 15 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action

[30] The boundaries between the sea basins as defined in the Directive 2008/56/EC.

Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Promote a considerable pipeline of new and advanced versions of existing technologies from lab to fab production, enabling robust continued performance increase, opening up new applications and facilitating further cost reduction.
- Reinforce the European PV value chain, support local companies to develop and sell differentiated and high value PV products and create local jobs.
- Demonstrate the feasibility and cost-competiveness of the novel PV technologies.
- Contribute towards establishing a solid European innovation base.
- Enable and facilitate large-scale deployment of PV and generation of renewable electricity.
- Minimise the impact of PV on landscape and environment by increasing its energy yield/m2.

Scope:

Net-zero scenarios modelled by the JRC[31] show that Europe must install up to 600 GW PV generation capacity by 2030 and over 1 TW by 2050 to reach its climate and energy objectives. The European market will grow 10-15% per year and reach close to 80 GW by 2030. In this race, Europe has a unique opportunity to develop and deploy new generation PV modules. A considerable number of new and advanced/innovative technologies is in the pipeline but the concrete application on pilot manufacturing lines is lagging behind. The aim is therefore to advance those technologies that offer the potential for much higher efficiency and/or higher energy yield, the same lifetime and degradation rate and comparable cost to standard crystalline technologies, opening-up possibilities for largescale 4.0 factories to drive down costs, allowing large relocation of production to Europe.

The proposal should address all of the following:

- Develop and demonstrate at pilot line level innovative or alternative and advanced versions of existing PV technologies: the pilot lines should show the feasibility and cost-competitiveness of industrial production of cells and modules.
- Develop corresponding manufacturing equipment.
- Implement Industry 4.0 concepts.
- Test and validate the performance characteristics of manufactured products (efficiency, durability, reliability, …).
- Demonstrate a business case for manufacturing plants of individual output capacity in the GW range and a market introduction strategy.

[31] https://doi.org/10.1016/j.rser.2020.109836

- Address the following related aspects: lower environmental impact, better resource efficiency than current commercial renewable technologies, circularity potential (including recycling and sustainability by design).
- Document all demonstrators fully and transparently to ensure replicability and up scaling, to assist future planning decisions.

The proposal should involve multidisciplinary consortia including industrial partners.

C5-D3-RES-18-2021: Demonstration of large-scale CHP technologies for a shift to the use of biogenic residues and wastes

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

<u>Expected Outcomes</u>: Project results are expected to contribute to some of the following expected outcomes:

- Advance the EU scientific basis and increase technology competitiveness in the area of bioenergy, in particular increase penetration of renewables, regional development, cost reduction and feedstock enlargement thus supporting the EU goals for climate protection, energy independence and economic growth;
- Technology de-risk retrofitting of large-scale fossil CHP to bioenergy as a necessary step before scaling up at commercial level;
- Allow high penetration in the energy system, ensure stability and security of energy supply and gain efficiency and costs in transforming the energy system on a decarbonised basis, in particular by reducing CAPEX for bioenergy capacity and base-load capability;
- Enhance sustainability of renewable energy and fuel value chains by addressing social, economic and environmental aspects.

<u>Scope</u>:

Demonstration of cost-effective and efficient technologies for retrofitting of fossil CHP systems to the complete use of regionally sourced sustainable biogenic residues and wastes or derived intermediate bioenergy carriers for continuous, cost-effective and low-emission operation. Proposals shall address long-term scenarios for flexible and modular operation within the energy system network and document all demonstrators fully and transparently, to ensure replicability, up-scaling and to assist future planning decisions.

Proposals that include ‘hybrid’ approaches that combine the use of renewable energy with the continued use of fossil fuels, are not eligible.

C5-D3-RES-19-2021: Demonstration of cost-effective advanced biofuel technologies utilizing existing industrial plants

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TR 6-7 by the end of the project – see General Annex D.

Expected outcomes: Scaling-up of advanced biofuel production requires heavy new infrastructure and investments, which impedes their capacity building. Utilizing existing industrial plants to integrate advanced biofuel technologies facilitates their capital-intensive commercialization. Demonstrating the effectiveness and technical feasibility of cost-effective integration of advanced biofuel technologies in existing plants will contribute to increase their competitiveness and facilitate their commercialization. This will allow high penetration of advanced biofuels in the transport energy system, in particular for hard to electrify sectors, like aviation and maritime where large volumes are immediately required. At the same time, it will promote more efficient reusing and circularity of industrial plants and create socio-economic benefits in local communities. These contributions accelerate getting closer to the European Green Deal and climate and energy targets for 2030 and to net zero greenhouse gas emissions by 2050, while supporting the EU goals for energy independence and economic growth.

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

- Reduce capital and operational expenses (CAPEX and OPEX) of advanced biofuel production facilities.
- De-risk technology, boost scale-up of advanced biofuels and contribute to their market up-take.
- Contribute to the priorities of the SET Plan Action 8.
- Respond to short and medium term needs for renewable fuels in transport.
- Create win-win solutions for advanced biofuel production and conventional industrial phasing out plants, e.g., first generation biofuels, associated with socio-economic benefits.

Scope:

Proposals should demonstrate cost-efficient advanced biofuel technologies which improve the economic viability of the advanced biofuel production. This should be done through innovative transformation of existing plants to incorporate production of advanced biofuels from non food/feed sustainable biomass feedstock into existing processes, e.g., first generation biofuel plants, paper mill industry, waste treatment plants, oil-refineries, petrochemical industry, etc. Integration of advanced biofuel processing should be done with new and innovative installations and it should be optimized implementing a circularity approach for energy and material, as well as digitalization as appropriate, e.g. by using sensors, smarter equipment, algorithms etc, to increase the efficiency, cost-effectiveness and performance of the final plant. Economic advantages in terms of both capital and operational expenditure for commercialization of advanced biofuels through transformation, as well as socio-economic benefits for phasing-out industries including the impact on current first generation biofuel sites should be addressed. Proposals should provide information about the expected economic improvements and the potential of full transformation to advanced biofuel plants as appropriate. All demostrators should be fully and transparently documented, to ensure replicability, up-scaling and to assist future planning decisions.

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.

C5-D3-RES-20-2021: Innovative biomethane production as an energy carrier and a fuel

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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 outcomes: Biomethane is a direct renewable substitute of natural gas and a flexible renewable energy carrier that can temporary and locally decouple production from utilization, provide energy storage capability and serve several end uses, such as electricity, heat and transport, utilizing existing gas networks distribution. Demonstrating advanced technologies for efficient production at scale of biomethane will contribute to facilitate commercialization of the biomethane technologies to allow its high penetration in the energy and the transport energy systems, in particular for gas consuming sectors, thus getting closer to the European Green Deal and climate and energy targets for 2030 and to net zero greenhouse gas emissions by 2050, while supporting the EU goals for energy independence and economic growth..

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

- Increase cost-effectiveness of biomethane production.
- Diversify technology basis for biomethane production.
- De-risk technology, boost scale-up of biomethane and its market up-take in the gas market.
- Contribute to the priorities of the SET Plan Action 8.

Scope:

Proposals will demonstrate cost-effective and innovative biomethane production through thermochemical, biochemical, chemical, electrochemical, biological pathways including biomass gasification, CO2 effluents from anaerobic digestion or fermentation processes combined with renewable hydrogen or water. The biomethane production should be optimized to improve production efficiency, reduce cost, minimize GHG emissions and increase sustainability in a circularity approach for energy and material above conventional technologies of biogas upgrading to biomethane. All demostrators should be fully and transparently documented, to ensure replicability, up-scaling and to assist future planning decisions.

C5-D3-RES-21-2022: Innovative components and/or sub-systems for CSP plants and/or concentrating solar thermal installations

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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 Outcomes:

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

- Higher efficiency of concentrated solar power (CSP) plants and/or concentrating solar thermal installations.
- Reduced maintenance costs of CSP plants and/or concentrating solar thermal installations.
- Achieve the targets of the SET Plan Initiative for Global Leadership in CSP.

Scope:

Support will be given to the demonstration of innovative, cost effective and more reliable components and/or sub-systems for CSP plants and/or concentrating solar thermal installations. The components and/or sub-systems will allow better efficiency in terms of solar energy conversion.

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

Projects shall assess the sustainability of the proposed components and/or sub-systems in environmental, social and economic terms.

All demostrators should be fully and transparently documented, to ensure replicability, up-scaling and to assist future planning decisions.

C5-D3-RES-23-2022: Demonstration of wave energy devices to increase experience in real sea condition

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of up to EUR 15 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting

	different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Demonstrated performance and reliability of wave energy devices producing comparable and public results using international metrics
- Improved knowledge on how to operate wave energy devices, availability maintainability and survivability and to increase the impact it is expected that projects are sharing project data.
- Contribute to LCOE reduction in line with the SET-Plan targets (actions should clearly state estimated LCOE at project start and end, using a recognised calculation methodology).
- Reinforce the industrial supply chain.
- Attract private investors to the sector and reduce the cost of this investment to projects by producing and publishing evidences and credible figures of key performance indicators.

Scope:

The action should:

- Demonstrate wave energy devices in real sea conditions for long periods of time (12-24 months) providing invaluable learnings regarding performance, reliability, availability, maintainability, survivability and environmental impact.
- Have verified key subsystems by comprehensive dry testing to reduce risks in advance of the project or will finalise successfully the dry testing in the first year of the project. The onshore testing should have been carried out prior to any at-sea deployment of complete devices.

Proposals should address also 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.

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, a plan to achieve certification by an independed certification body before the end of the action, and all needed permits for the deployment of the project. The project proposal should clearly demonstrate a proposed pathway to obtaining necessary permits for the demonstration actions and allow for appropriate timelines to achieve these. The project should also 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.

C5-D3-RES-26-2021: Sustainable solutions for renewable energy and fuel technologies

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 2,5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

The EU has ambitious goals to tackle the ongoing climate crisis, noteworthy being the aim to be a fully climate-neutral continent by 2050. Thus there is a clear need to coordinate actions and to engage with stakeholders at different levels (policymakers, regulators, innovators, industry, trade associations, local communities) in order to align priorities and needs, while also identifying possibly overlooked challenges.

In this context, and taking into consideration circularity and sustainability, project results are expected to contribute to all of the following expected outcomes:

- Enhance and promote sustainability by addressing social and environmental aspects at a global level, thus ensuring the European Green Deal priorities are met;
- Support the development of training and reskilling efforts, while also identifying (global and local) challenges, to realise the large deployment ambitions of the European Green Deal and its external dimension;
- Support and promote circularity concepts and approaches in line with the Circular Economy Action Plan and the Action Plan on Critical Raw Materials.

<u>Scope</u>:

The proposal should:

- Coordinate the stakeholder community and propose concrete actions to promote and accelerate the development of sustainable solutions for renewable energy and fuel technologies encompassing ‘circularity by design’, with special attention to life cycle assessment of the entire value chain including critical raw materials and gradual substitution of fossil fuels;
- Set up and initiate a structured programme to promote an innovative multi-disciplinary approach on teaching and engaging with renewable energy. The proposal should also actively engage with European universities in this matter. Special consideration to gender balance issues must also be given. A clear post-project life for such programme should also be addressed;
- Develop and run an industry-academia programme focused on hands-on training. This programme should identify the required skills needed for renewable technologies, identify and act on knowledge gaps, and identify retraining opportunities. These concerted actions must develop human capital through education and training.

C5-D3-RES-27-2022: Digital solutions for defining synergies in international renewable energy value chains

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 2,6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Eligibility	The conditions are described in General Annex B. The following exceptions apply: In addition to the minimum requirements set out by General Annex B the project must include at least one beneficiary from a Mission Innovation Country, not being Member State or Associated Country
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Advance the EU and global scientific basis, leadership and global role in the area of renewable energy and renewable fuels and related energy value chains while creating evidence for policy making by developing novel digital solutions;
- Provide digital breakthrough solutions for promoting the increase of the global renewable energy share;
- Reinforce the EU scientific basis through international collaboration while increasing the potential to export EU renewable energy technologies and ensuring political priorities in the context of global energy value chains.
- Improve reliability of system components, advanced and automated functions for data analysis, diagnosis and fault detection, forecasting and model-predictive control frameworks, ancillary services for the stability of the network; maintenance planning and/or reporting

Scope:

Development of novel real time and open data monitoring and/or simlulation solutions (e.g. including digital twins) for production and consumption, predictive modelling and artificial intelligence for the analysis of international renewable energy value chains and for internationally aligned decision-making in cooperation with international partners from Mission Innovation Countries. To ensure trustworthiness, wide adoption by user communities and support EU policy-makers, actions should promote the highest standards of transparency and openness, going well beyond documentation and extending to aspects such as assumptions, models and data related to renewable energy and fuels.

C5-D3-RES-28-2022: Best international practice for scaling up sustainable biofuels

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of EUR 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex D.

Expected outcomes: The increase of renewable fuels share in transport is the smallest than all renewable energy shares in other sectors globaly, as scaling up of sustainable biofuels which is the most readily available renewable fuel is challenging. Many countries around the world, recognizing the need of including sustainable biofuels in their transformed integrated energy system, participate in the Mission Innovation challenge of sustainable biofuels to cooperate in fostering their scaling-up. Enhancing the EU part will contribute to advance the EU global role in the area of renewable fuels, increase the potential to export EU renewable fuel technologies into global developing markets, and enhance sustainability of biofuel value chains worlwide while supporting the EU goals for climate change mitigation in 2030 and 2050.

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

- Build global knowledge for the scaling-up and the sustainability assessment of sustainable biofuels value chains.
- Contribute to cost-effective and more sustainable large-scale production of sustainable biofuels.
- Contribute to Mission Innovation Challenge n°4 Sustainable Biofuels.
- Contribute to the SET Plan Action 8 Bioenergy and Renewable Fuels for Sustainable Transport.
- Accelerate capacity building for sustainable biofuels in the world.
- Develop networks for skill development and knowledge sharing in sustainable biofuels value chains worldwide.

Scope: Proposals will aim at fostering international cooperation to develop best practices and concepts along the entire value chain for accelerating the scale-up of sustainable biofuels worldwide. Scaling up sustainable biofuels is a global challenge in terms of environmental, social, and economic sustainability, which can benefit from international collaboration and knowledge exchange. Proposals should address systemic constraints and opportunities for scaling up complete value chains of sustainable biofuels and propose solutions. Any sustainable non food/feed biomass feedstock and any innovative technology or combinations of them should be considered. Proposals should enhance overall cost-effectiveness and sustainability of large scale production of sustainable biofuels based on Life Cycle Analysis addressing social, economic and environmental aspects. International cooperation with Mission Innovation countries is expected.

C5-D3-RES-29-2022: AU-EU Energy System Modelling

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 2,5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Eligibility	The following exception apply: In addition to the conditions described in General Annex B, three partners from three different African countries must be part of the consortium.

Expected outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Contribute and reinforce to the AU-EU HLPD CCSE Partnership.
- To advance knowledge and scientific proofs of the water energy food nexus and of its concept including the environmental, social and economic benefits
- To contribute towards establishing an evidence base for decision making
- To contribute to increase clean energy generation in the African energy systems
- To create African experts and expertise in this area

Scope:

The topic is contributing to the activities of the AU-EU High Level Policy Dialog (HLPD) Climate Change and Sustainable Energy (CCSE) partnership. Current models are based on developed country standard and usage. The development of energy system models tailored to the specific African social, economic and regulatory environment is crucial for energy generation system planning and for energy policy development. Today African countries are relying heavily on developed country models and expertise.

Therefore, the proposal should develop and test models for decision makers and planners to design and evaluate energy system(s) with a high penetration of renewable energy systems in African countries through a regional approach. Considerations are to be given to decarbonisation, using no fossil fuels, of cities and industries. A focus should be made on the introduction of clean energy technologies. The tests should be done for at least two base cases.

Proposals should include activities to coordinate with the project(s) to be selected under the topic C5-D3-RES-01-2021.

Actions should promote the highest standards of transparency in model adoption, including assumptions, architecture, code and data. The outcome of the project should be widely disseminated and the source code of the model to be open access to stimulate future development. To ensure future uses African experts, in energy, but also in models development should be full partners in the project. The project should identify further local training needs.

The project should make use of existing European activities to create synergies and cross-fertilisation.

The project will contribute to the work of the AU-EU HLPD CCSE partnership through networking activities with existing projects.

C5-D3-RES-30-2022: Efficient and circular artificial photosynthesis

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Advance the EU scientific basis, leadership and global role in the area of renewable and solar fuels, while creating evidence for policy making;
- Provide solar fuel breakthrough solutions towards a fossil-free economy and ecosystem by bridging solar energy and fuel needs with the potential of high penetration in the energy system, ensuring stability and security of energy supply;
- Increase EU technology competitiveness in solar fuel technologies, thus supporting the EU goals for climate protection, energy independence and economic growth.
- Develop artificial photosynthesis solutions, which will minimize further downstream processing and increase their scalability and integration within the industrial value chain in respect of circularity

Scope:

Development of novel artificial photosynthesis technologies, which allow for improved efficiency of light harvesting, conversion to electrochemical potential and energy fixation to carriers with strictly implementing circularity by design and efficient use of carrier (photo)catalyst materials through novel photoelectrochemical or bio-based (bio-hybrid) or biological pathways for solar fuel production with increased efficiency in comparison to light and dark reactions of natural photosynthesis. Production of H2 as a final product is excluded.

C5-D3-RES-32-2022: Integrated wind farm control

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Award criteria	In order to ensure a balanced portfolio, at least the highest ranking

	proposal addressing offshore wind farms and the highest ranking proposal addressing onshore wind farms will be funded, provided they attain all thresholds. This condition to ensure a balanced portfolio will also considered to be met if one project addressing both aspects is funded.
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

Expected outcomes:

Wind turbines and wind farms are increasingly more equipped with and reliant on sensors, IoT devices, and data-driven approaches in general. This next generation of wind farms will need to be supported by an even more innovative set of tools to unlock their full potential on low-cost reliable clean energy generation.

In this context, project results are expected to contribute to all of the following expected outcomes:

- Development of open source data-driven tools to decrease energy costs on operation, while increasing total wind farm output, and of a common research framework for evaluating the risks associated with digital/AI solutions, including cybersecurity aspects;
- Development of digital and physical tools, as well as interoperable frameworks, for enhanced data collection and analysis aimed at increased farm output;
- Allow operators to make better informed decisions on farm-wide system optimisation, lifetime extension, decommissioning and/or recycling of components.
- Contribute to LCOE reduction in line with the SET Plan targets (actions should clearly state the estimated LCOE at project start and end).

Scope:

The proposal should:

- Address and validate how digital innovation on wind farm control are able to provide more stable, resilient, reliable and affordable energy, while retaining high levels of cybersecurity. Focus on farm output maximization and/or reduced component load is encouraged.
- Address how these data-driven innovations reduce operational and maintenance costs, increase energy output, and their impact on (component, turbine, farm) lifetime;
- Address the role of such innovations as a prognostic tool, regarding failures and damages:
- Develop and release an open source digital/AI solution for sector uptake. This tool should be built from concrete experiments and data measurements. Further, it should account for the emergence of large wind turbines (up to 20 MW) and include those in the development of this tool.

In order to optimise impact and enhance synergies, cooperation with projects from the C5-D3-RES-04-2021 call is particularly encouraged.

C5-D3-RES-33-2022: Novel thin-film (TF) photovoltaic technologies targeting high efficiencies

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Increase the potential of thin-film technologies for mass production, low cost and/or specialised applications.
- Reinforce the European PV value chain, support local companies to develop and sell differentiated PV products.
- Allow for an efficient use of available areas for renewable energy generation/ reducing competition between different kinds of land use by further increasing PV energy yield/m2.
- Enable and facilitate large-scale deployment of PV and generation of renewable electricity.

Scope:

An alternative to c-Silicon PV is thin-film solar cells, which can be fabricated on various and flexible substrates (including glass, metal foils and polymers). A benefit of thin-film PV is the lower direct semiconductor materials cost. Realising lower costs in production requires high input material utilisation and low raw materials conversion costs. Largescale thin-film module production can be more cost efficient when utilising rapid processing technologies. With further advances in scientific understanding, 25% efficiency devices are within reach as are even higher efficiencies in tandem architectures. Translating those device and process advances to manufacturing technology will dramatically reduce LCOE once sufficiently scaled in both module size and production volume. This will require adapting deposition processes for higher rates and to larger-scale equipment while developing suitable robust techniques for inline process and quality control.

The proposal should address all of the following:

- Develop novel environmentally benign thin-film technology concepts that optimise PV cell and module architecture, increase durability, decrease losses (minimising also the cell-to-module efficiency gap) and target very high efficiencies (>25%) with flexibility for specific applications.
- Employ simple, scalable and low cost/low energy consumption and higher rate deposition processes.
- Perform device/module real–life (under actual outdoor operating conditions) characterisation for reliability and energy yield assessment.

- Perform a life cycle analysis to bring evidence of the lower environmental impact, better resource efficiency than current commercial PV technologies, and circularity potential.

C5-D3-RES-34-2022: Efficient and low-emission technologies for industrial use of combustion and gasification systems from low-value biogenic residues and wastes

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Advance the EU scientific basis, technology base, leadership and global role in the area of bioenergy integration into industrial settings while creating evidence for policy making;
- Increased feedstock diversification and better technological performance leading to cost-reduction of bioenergy with positive effects on renewables' penetration, circularity and security of supply
- Reduced emissions and increased environmental and socio-economic sustainability of biomass combustion and gasification and bioenergy value chains

Scope:

Development of technologies for optimization of advanced biofuel flexible systems regarding upstream multi-feedstock, logistics, feeding, ash management, combustion or gasification processes and effluent emissions and their effective integration into industrial process energy environment through efficient and low-emission technologies for industrial use of combustion and gasification systems from low-economic value, but fully sustainable biogenic residues and wastes.

C5-D3-RES-35-2022: Development of algal and renewable fuels of non-biological origin

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Award criteria	At least one algal fuel project will be funded.

Technology or societal readiness level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex D.

Expected outcomes: Renewable fuels of the future will be also based on algae and non-biological feedstock for sectors that depend on and operate with dense fuels. Improving these technologies will contribute to advance the EU scientific basis and global technological leadership in the area of renewable fuels, increase their technology competitiveness and role in transforming the energy system on a fossil-free basis by 2050, in particular for hard to electrify sectors like aviation, while supporting the EU goals for energy independence.

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

- Increase feedstock and technology basis for renewable fuels.
- Facilitate development of advanced and high-quality biofuels from algae vegetable lipids.
- Foster development of technological pathways for algal and non-biological renewable fuel production.
- Increase robustness of conversion and process sustainability for algal and non-biological renewable fuels.
- Contribute to the priorities of the SET Plan Action 8.
- Deliver technology for longer-term needs for renewable fuels in energy and transport.

Scope:

Proposals will develop and improve algal and/or non-biological renewable fuel technologies through developing synthetic pathways including biological, biochemical, thermochemical, electrochemical processes or combinations of them. Improving the performance of the conversion process by increasing the efficiency, reducing the cost and decreasing the GHG emissions from the production should be addressed beyond the current state of the art. Implementing and improving circularity for energy and material use should be considered, also as a means to enhance sustainability and economic feasibility of the proposed concepts. Proposals should also address systemic constraints and opportunities for scaling-up algal and non-biological renewable fuel technologies. Production of H2 as a final product is excluded.

C5-D3-RES-37-2021: Solutions for more sustainable geothermal energy

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of approximately EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Performance and reliability improvement of deep-geothermal systems.
- Reduced environmental impact of geothermal plants
- Reduced risk of seismicity
- Increased citizen engagement for geothermal energy
- Contribute to LCOE reduction approaching SET-Plan targets (actions should clearly state estimated LCOE at project start and end).
- demonstration of 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 proposal should

- develop and validate innovative sustainable circular-by-design solutions that can reduce environmental impact and increase the overall circularity of geothermal energy The following can be considered:
    - capture of greenhouse gases, storage or reinjection schemes for the development and exploitation of geothermal reservoirs, in particular those with high content of non-condensable gases (NCGs), and the use of alternative fluid to brine.
    - techniques for reservoir development and exploitation in a wider range of geological settings, including complex and/or untested geological conditions
    - potential introduction and demonstration of the innovative technologies as part of existing geothermal plants in Europe and abroad.
    - novel methods and technologies to find and develop productivity from near magmatic, superhot/supercritical zones that are currently unexploitable and non-commercial.

C5-D3-RES-40-2022: Development of digital solutions for existing hydropower operation and maintenance

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 4.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Advance the EU scientific basis, technology base, technology leadership in the area of hydropower in the context of digital transition and energy markets while creating evidence for policy making;
- Increase the technology competitiveness of the existing hydropower fleet in changing EU power markets by increasing hydropower flexibility and decision-making in modern power markets;
- Facilitate market penetration of renewables and getting closer to the European Green Deal and climate and energy targets for 2030 by increasing the flexibility, sustainability and predictability of existing hydropower;
- Improve environmental and socio-economic sustainability of the existing hydropower fleet.

Scope:

Development of novel sensor technologies and digital solutions for digitization of existing hydropower plants by addressing one or more of the following: weather and flow forecast, biodiversity monitoring, predictive modelling and artificial intelligence for the analysis of sensor data for decision-making in operation and maintenance. To ensure wide uptake and reliability, actions should promote the highest standards of transparency and openness of the digital solutions, extending to aspects such as assumptions, architecture, code and data.

C5-D3-RES-41-2022: Demonstration of innovative materials, supply cycles, recycling technologies to increase the overall circularity of wind energy technology and to reduce the primary use of critical raw materials

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 13 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Award criteria	In order to ensure a balanced portfolio, at least the highest ranking proposal of each activity will be funded, provided it attains all thresholds. This conditions to ensure a balanced portfolio will also considered to be met if one proposal addressing both aspects is funded
Technology or societal readiness level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex D.

Expected outcomes:

In order to achieve the goals of climate-neutrality by 2050, renewable energy sources installations will have an explosive growth. Wind energy, in particular, will play a large role on supplying clean energy to the electrical grid. Nevertheless, this growth must be done in a sustainable manner and following the principles set out in the Circular Economy Action Plan and the Action Plan on Critical Raw Materials. Thus, clear and decisive actions will need to be taken now to assure that the future wind farms are sustainable and circular, while also dealing with current wind farms and the recycling of their components, once they reach the end of their lifetime. The nature of this challenge involves different kinds of activities.

The first activity is on the development of large-scale industrial demonstration of composite material recycling technologies to increase the circularity of wind technology. This demonstration will focus on flexible approaches for composite recycling, and on the development of a knowledge hub involving other composite-heavy sectors, in order to share best practices and to identify common challenges.

Another activity is on the development of alternative solutions to replace/substitute critical raw materials. Further constraints linked to the availability of rare earths elements used in the wind sector, in particular for permanent magnets, are also relevant in this context.

The project results are expected to contribute to the promotion of the ‘circularity by design’ approach in the wind energy sector, and to support the adoption of life cycle assessment tools, demonstrating reduced carbon footprint on the wind turbine value chain.

<u>Scope</u>:

The proposal must address at least one of the following activities:

- On the development of large-scale industrial demonstration of composite material recycling technologies to increase the circularity of wind technology, proposals should demonstrate recycling technologies at large-scale in an operating environment. The proposed solution will be a flexible production line, able to deal with a large amount of material (including coatings, paints) and applicable to several manufacturers and possibly to other sectors. The proposed solution must also have a long-term plan, with a business plan, beyond the life of the project. The proposals will also build a knowledge hub within the sector and with other sectors to transfer information and to promote recycling in the renewable energy sector and ‘circularity by design’ as a solution.
- On the development of alternative solutions to replace/substitute critical raw materials, proposals should develop, validate and demonstrate, in a relevant environment, solutions and their supply cycles, improving efficiency of sourcing processes and effectively replacing the constrained materials. The development of advanced ‘circular by design’ materials is also be considered. The solutions proposed should be in line with the Action Plan on Critical Raw Materials [32]and the Foresight Study on Critical Raw Materials for Strategic Technologies and Sectors in the EU[33]. Finally, the proposals will indicate the effect that such proposed solutions have on promoting circularity and/or recyclability on wind energy, as well as their circularity potential, their financial feasibility, and their potential to be upscaled. Further, the proposals should address and support life cycle analysis as a tool to bring into evidence the environmental impact and resource efficiency of proposed solutions.

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[32] COM(2020) 474 - Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability

[33] Critical Raw Materials for Strategic Technologies and Sectors in the EU - A Foresight Study

Independently of the activity tackled, the proposal has to include a clear go/no go moment ahead of entering the deployment phase. Before this go/no-go moment, the project will have to deliver the detailed engineering plans, a complete business and implementation plan and all needed permits for the deployment of the project. The proposal should clearly demonstrate a proposed pathway to obtaining necessary permits for the demonstration actions and allow for appropriate timelines to achieve these. The proposal should also 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.

C5-D3-RES-43-2022: Advanced manufacturing of Integrated PV

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 15 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Reinforce the EU PV value chain, support local companies to develop and sell differentiated IPV products and create local jobs.
- Demonstrate that automated manufacturing of integrated photovoltaics (IPV) can deliver cost competitive products assuming both the function of energy generators and of structural elements.
- Enable and facilitate large-scale integration of PV in buildings in line with the concept of “positive energy buildings”, in infrastructure, transport, agriculture, etc..

Scope:

“Integrated PV” stands for photovoltaics that are embedded into components fulfilling other functions. The most well-known and developed application currently is Building Integrated PV (BIPV), in which PV is integral part of construction elements (tiles, façades, cladding, …) and assembled to constitute a system replacing a conventional building envelope solution. However, other Integrated PV (IPV) solutions are markedly emerging, for example in infrastructure (IIPV), in the automotive industry (VIPV), in agriculture, etc. In addition to the overall PV goal of lowering the LCOE, IPV applications can bring the extra value of decentralized, point-of-use electricity generation and simultaneously fulfil another functions such as of a roofing, facade or sound barrier. Progressively developing and having the potential for a world-wide market with huge opportunities for the European industry, manufacturing of customized IPV in series production concept needs to be developed to bring down the cost of Integrated PV allowing for largescale production and use.

The proposal should address all of the following:

- Demonstrate at pilot line level flexible automated manufacturing for:

- differentiated product design (format, different thicknesses of substrate and variations in the solar cell matrix, encapsulation material, frontsheet, etc.) respecting freedom of design and aesthetics for various applications;
- integration of advanced robust techniques for inline process and quality control;
- equipment design easily adaptable to rapidly emerging novel cell and module technologies;
- high product efficiency and durability at competitive costs, in conformity with codes and standards of integrated photovoltaics (IPV) use.

- Implement Industry 4.0 concepts.
- Demonstrate a business case and a market introduction strategy.
- Facilitate the ‘renovation wave’ by establishing an active collaboration between the PV sector and the building industry for seamless industrial construction/renovation workflows.
- Address the following related aspects: low environmental impact, resource efficiency and circularity potential.

The proposal should involve multidisciplinary consortia including industrial partners.

C5-D3-RES-44-2022: Recycling end of life PV module

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 6 and 7 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Demonstrate efficient, low-cost, emerging recycling technologies for PV modules/products.
- Increase recyclability and minimise the environmental impact of PV technology.
- Introduce new business models and open new markets in PV recycling.
- Reduce dependency on primary raw materials through the circular use of resources, sustainable products and innovation.
- Strengthen domestic sourcing of raw materials in the EU.

Scope:

PV technology is undergoing a transition to a new generation of efficient, low-cost products based on various photoactive materials. PV technology has definite environmental advantages over competing electricity generation technologies, and the PV industry follows a pro-active life-cycle approach to prevent future environmental impact and to sustain these advantages. However, long-term sustainability of photovoltaics will be largely dependent on the effectiveness of the process solutions that will be adopted to recycle the unprecedented volume of end-of-life panels/products expected to be generated in the near future. Recycling is indispensable to avoid the loss of the valuable materials employed to produce photovoltaics and, at the same time, prevent harmful elements, including, for example, heavy metals, to be dispersed into the environment through improper disposal practices.

The proposal should address all of the following:

- Forecast the PV waste streams and estimate the market potentials.
- Develop and demonstrate flexible, high efficiency and throughput recycling technologies adapted to the large volumes of PV modules/products that will be disposed in the near future, depending on the typologies of cells/modules/products and reverse logistics.
- Demonstrate re-use potential of high-value recycled material (maintaining its purity and/or integrity) in the PV sector.
- Demonstrate a business case for the concept and a market introduction strategy.
- Address the following related aspects: low environmental impact, resource efficiency and circularity potential.

The proposal should involve multidisciplinary consortia including industrial partners.

C5-D3-RES-46-2022: Innovative renewable energy carrier production for heating from renewable energies

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Advance the EU innovative knowledge basis and increase technology competitiveness in the area of energy carrier production and heating value chains, in particular increase of feedstock availability for renewable heating, thus supporting the EU goals for climate protection, energy independence and economic growth;
- Technology de-risk of renewable energy carrier value chains as a necessary step before scaling up at commercial level;
- Enhanced sustainability of renewable heating value and supply chains by improving techno-economic efficiency and minimising negative environmental effects.

Scope: Demonstrate cost-effective and energy-, catalyst and equipment material-efficient transformation of renewable energy into renewable energy carriers for heating, while ensuring very good combustion properties in respect of efficieny and avoidance of pollutants and environmental and socioeconomic sustainability of the respective heating supply and value chains.

C5-D3-RES-47-2022: Demonstration of complete value chains for advanced biofuel and non-biological renewable fuel production

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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 outcomes: Complete value chains for advanced biofuels and renewable fuels of non-biological origin provide a systemic understanding of the value created and the constraints in individual chain steps. Demonstrating such complete vale chains will contribute to increase the competitiveness of their technologies and foster their commercialization to allow high penetration of advanced biofuels and renewable fuels of non-biological origin in the energy and transport energy system, in particular for hard to electrify sectors. This in turn will accelerate achievement of the European Green Deal and climate and energy targets for 2030, while supporting the EU goals for energy independence and economic growth.

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

- Build a portfolio of complete value chains for advanced biofuels and renewable fuels of non-biological origin.
- De-risk technology, boost the scale-up of advanced biofuels and non-biological origin renewable fuels.
- Contribute to the priorities of the SET Plan Action 8.
- Respond to short and medium term needs for renewable fuels in energy and transport.
- Improve sustainability and security of the value chains.

Scope:

Proposals should demonstrate innovative and cost effective sustainable value chains for advanced biofuels or synthetic renewable fuels of non-biological origin over the entire cycle from feedstock to end use. Any sustainable biomass feedstock including residues and wastes, or biogenic CO2 or industrial CO2 and renewable hydrogen, as well as input energy to the conversion should be addressed. Pathways which are biochemical, thermochemical, biological, chemical, electrochemical or combinations of them should be considered. Proposals should aim at improved performance in terms of increasing the efficiency and sustainability and reducing the cost, while evidencing the value creation along the value chain steps. Complete value chains may address any relevant end use. Value chains of H2 as a final product are excluded.

C5-D3-RES-49-2022: Demonstrate the use of high temperature geothermal reservoirs to provide energy storage for the energy system

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution up to EUR 17.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Performance and reliability improvement of geothermal systems.
- Reduced environmental impact of geothermal plants.
- Increased citizen engagement.
- Contribute to LCOE reduction approaching SET-Plan targets (actions should clearly state the estimated LCOE at project start and end).

<u>Scope</u>:

High-temperature underground thermal energy storage (HT-UTES) covers the 25-90°C temperature range, and the targets of interest can reach up to 2000 m in depth. The development of UTES is linked to a multidisciplinary understanding of the whole system, including waste-heat source, exploration and subsurface characterisation, production, implementation and distribution systems, as well as the adaptation of the regulatory framework and social acceptance. The main technical challenges are the adaptation of the return temperature from the surface site to the subsurface temperature and to the regulatory frameworks, identification, characterisation and monitoring the reservoirs for UTES, the geo-mechanical effects of the reservoir linked to the seasonal injection/ production operations related to pressure and temperature changes, hydrogeochemical problems associated with scaling and corrosion of the piping system, circular design and optimisation of the distribution network.

The proposal should:

- Develop and demonstrate appropriate control systems and infrastructure to manage geothermal heat and electricity production, heat demand and storage connected to the installation.
- Use the flexibility of geothermal reservoirs as thermal energy storage systems and flexibility in the network coping with daily, weekly and seasonal variations in heat demand.

- Demonstrate the innovative technologies in at least 2 different plants with different characteristics.

C5-D3-RES-50-2021: Demonstration of innovative rotor, blades and control systems for tidal energy devices

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution up to EUR 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Demonstrated increased performance (>20%) and reliability of tidal energy devices
- Knowledge on how to operate tidal energy devices, availability, maintainability and survivability
- Contribute to LCOE reduction approaching SET-Plan targets (actions should clearly state the estimated LCOE at project start and end using a recognised calculation methodology)
- Reinforce the industrial supply chain
- Attract private investors to the sector and reduce the cost of this investment to projects by producing and publishing evidences and credible figures of key performance indicators

Scope:

There is a need for further technology investigation and demonstration for improved reliability and efficiency of tidal turbine rotor and blades, including control and condition monitoring systems. Failure in a blade can create long downtimes, for instance blade edges can erode rapidly, facilitating water ingress, accelerating fatigue and the risk of failure. There are different blade solutions under development in terms of shape and material. Improving the seaworthiness of rotor and blades will reduce the likelihood of failure, reduced annual energy production and increases in operating costs.

The proposal should:

- Demonstrate innovative rotor and blade solutions including condition monitoring systems for tidal energy devices in real sea conditions for long periods of time providing invaluable learnings regarding performance, reliability, availability, maintainability, survivability and environmental impact.
- Apply high performance computing and digitalisation (e.g. data processing, machine learning and data analytics methods for implementation in data driven design, digital twins and control and monitoring for O&M).

C5-D3-RES-56-2021: Market Uptake Measures of renewable energy systems

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 2 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

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

- facilitate the wider uptake of renewable energy systems in the energy, industrial and residential sectors leading to an increase share of renewable energy in the final energy consumption by 2030 and beyond;
- contribute to substantial and measurable reductions in the project development timings and efforts
- contribute to provide a basis for the development of more informed policy, market support and financial frameworks, notably at national, regional and local level
- contribute to the development of markets 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
- identify lessons learned that could be shared with and extrapolated to partner countries to support their green energy transition

Scope:

The proposal will develop solutions addressing one or more of the identified challenges for the entire renewable energy market or focusing on a specific energy sector, such as electricity, heating, cooling or renewable fuels, or specific geographical issues such as urban and peri-urban areas, or landscape and cultural heritage. Self-consumption can be addressed. International aspects, such as collaboration and opening new markets, can be addressed as well.

The proposed solution can be developed to address a local challenge but should have wide potential for reapplication. The solution must 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.

C5-D3-RES-61-2022: Technological interfaces between solar fuel technologies and other renewables

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4 by the end of the project – see General Annex D.

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

- Advance the EU scientific basis, technological leadership and global role in the area of renewable and solar fuels, while creating evidence for policy making;
- Provide breakthrough solutions towards a fossil-free economy and ecosystem by bridging solar energy and other renewables in boosting renewable fuel production and storage with the potential of strongly reducing CAPEX and OPEX/toe, high penetration in the energy system, ensuring stability and security of energy supply;
- Increase EU technology competitiveness in solar and renewable fuel technologies, thus supporting the EU goals for climate protection, energy independence and economic growth.

Scope:

Development of energy transmitting technological interfaces to couple solar fuel technologies to other renewables as from e.g biosources, which allow for efficient feed in of other forms of renewable energy into solar fuel conversion technologies and allow for efficient and continuous renewable fuel production.

C5-D3-RES-62-2022: Demonstration of innovative plug-and play solutions for system management and renewables storage in off-grid applications

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness	Activities are expected to achieve TRL 8 by the end of the project – see

level	General Annex D.

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

- Advance the EU innovative knowledge basis, technology base, technology leadership in the area of renewable energy-based off-grid energy systems, while creating evidence for policy making in the context of off-grid energy systems
- Improve environmental and socio-economic sustainability of the renewable-energy off-grid systems, particularly on geographic energy islands and in Africa.
- Technology de-risk through prototype demonstration tested and validated in operational environment as a necessary step before scaling up at commercial level
- Reinforce the EU scientific and innovation basis through international collaboration on off-grid energy systems while increasing the potential to export EU renewable energy technologies and ensuring political priorities

Scope: Demonstration of innovative plug and play solutions for system management and renewables storage in off-grid applications, which allow for increase of renewables penetration for electricity and heating/cooling and are deployable under different climatic conditions, while also addressing cost-effectiveness, energy poverty and security of supply and by promoting prosumer renewable energy in off-grid cities and communities (including on geographic islands).

C5-D3-RES-63-2022: Renewable energy carriers from variable renewable electricity surplus and carbon emissions from energy consuming sectors

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 9 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Advance the EU scientific basis and increase technology competitiveness in the area of energy carrier production and integration with renewable electricity and carbon value and supply chains
- Technology de-risk of renewable energy carrier value chains through demonstration as a necessary step before scaling up at commercial level;
- Enhanced sustainability of renewable energy carrier value and supply chains by improving techno-economic efficiency and avoidance of CO2/GHG emissions and renewable electricity economic or curtailment losses and supported by a life cycle assessment.

Scope:

Demonstration of renewable energy carrier synthesis from variable renewable electricity surplus and carbon emissions from energy consuming sectors via improvement of their overall synthesis value chain efficiency and viability while making best use of their CO2 emissions in synergy with renewable electricity generation. The incorporation of hybrids of renewable electricity with algal or synthetic renewable fuels in energy intensive sectors by integrating the conversion of surplus renewable electricity and carbon emissions from these sectors to liquid renewable energy carriers by algal, artificial photosynthesis or homologuous non-solar pathways will be demonstrated. Conversion technologies must be based upon biological, biochemical, thermochemical and or electrochemical processes.

Avoid curtailing of renewable electricity and carbon emissions and improve overall efficiency and viability of renewable electricity assemblies in synergy with reduction of carbon emissions.

C5-D3-RES-65-2022: Direct renewable energy integration into process energy demands of the chemical industry

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex D.

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

- Advance the EU scientific basis, technological leadership and global role in the area of renewable integration into the chemical industry, while creating evidence for policy making;
- Increase EU technology competitiveness in renewable process energy technologies, thus supporting the EU goals for climate protection, energy independence and economic growth;
- Provide breakthrough solutions towards a fossil-free economy and ecosystem;
- Allow high penetration in the energy system, ensure stability and security of energy supply, including integration of local resources,and gain efficiency and costs in transforming the energy system on a fossil-free basis;
- Enable transformation of the energy supply to socio-economic and environmental fossil-free sustainable solutions across energy intensive chemical industry, targeting in particular process energy and its GHG emissions.

Scope:

Development of the technology and the methodology of integrating renewable energy in chemical processing by substituting fossil process energy in chemical industry, which has a high carbon footprint due to processing relative to the mass of the final product. Persued technology developments must directly target renewable energy integration into process energy demands of the chemical industry beyond electricity (targeting e.g. electrochemical potential of artificial photosynthesis to chemical reduction processes and/or e.g. direct solar thermochemical conversion) and should improve GHG balance and sustainability of the targeted process.

C5-D3-RES-67-2022: Novel Agro-Photovoltaic systems

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 4.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Harvesting of crops and photovoltaic electricity, providing sustainable solutions for energy production/use/efficiency, soil protection and water conservation.
- Reinforce the European PV value chain, introduce new business models and open new markets for novel Agro-Photovoltaic systems.

Scope:

Agro-Photovoltaics (or Agrivoltaics) denotes approaches to use agricultural areas simultaneously to produce crops and to generate PV electricity. In this way, Agro photovoltaics increases land-use efficiency and enables PV capacity to be expanded solving the problem of energy poverty in the agricultural sector, while still retaining fertile arable areas for agriculture.

The proposal should address all of the following:

- Develop and demonstrate agro-photovoltaic systems or building integrated agro-photovoltaic systems for green houses employing PV cell technologies/systems that allow and are adapted to appropriate growth conditions (plant variety and local geography) and at the same time produce electricity covering all year-through energy needs (e.g. for cooling/heating, watering, etc.) and increased crop yield.
- Demonstrate feasibility, reliability, replicability, robustness and ease of maintenance of the system and its performance using relevant KPIs (for e.g. ground coverage ratio, energy and agricultural yield, spatial efficiency, etc.).
- Demonstrate a business case for the concept and market introduction strategy.
- Address the following related aspects: low environmental impact (avoiding or minimizing land impact from PV systems), resource efficiency and circularity potential.

- Include a strong involvement of citizens/civil society, together with academia/research, industry/SMEs and government/public authorities.

C5-D3-RES-68-2022: Renewable energy incorporation in agriculture and forestry

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 7 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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 outcomes: Meeting local and seasonal energy demands in agriculture and forestry with optimum agricultural and forestrial waste management and use while reducing the associated emissions is essential. If not managed, agricultural waste is often burned in the fields and forests suffer from fires, thus increasing the environmental footprint of agriculture and forests. Soil and biodiversity improvement in agriculture could also benefit from renewable energy technologies. Demonstrating incorporation of renewable energy technologies to attain heat, waste and land management needs in agricultural and forestry will contribute to increase the penetration of renewable sources in the energy system and enable transformation of the energy supply across critical energy-consuming sectors, thus accelerating the achievement of the European Green Deal and climate and energy targets for 2030 and of net zero greenhouse gas emissions by 2050, while supporting the EU goals for energy independence and economic growth.

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

- Promote decentralised renewable energy use and cost-efficient decentralized production of renewable energy carriers.
- Reduce agriculture and forestry carbon footprint from own energy consumption and agricultural/forestrial waste management.
- Increase sustainability and circularity in agriculture while creating positive effects on biodiversity.
- Increase sustainability and circularity in forestry.
- Foster regional development in rural areas.
- Support farmers' and foresters' engagement as prosumers of renewable energy.

Scope:

Proposals should demonstrate incorporation of renewable energy technologies in agriculture or forestry to meet its electricity, heat, cold, waste and land management needs. Solutions should combine innovative renewable, circular and regional value chains from different renewables and adapted storage options to de-fossilize agricultural or forestrial processes trans-seasonally, taking into account hybridization compatibility. They should also address one of the two options:

- Transformation of agricultural or forestrial wastes to renewable energy carriers in situ, e.g. by modular slow pyrolysis units, using renewable energy for process energy needs. Solutions should improve the cost-effectiveness and the sustainability of agriculture or forestrial seasonal energy demand based on renewables.
- Development of renewable-based agricultural protocols for multiple and cover cropping and/ or mixed cropping which increase carbon sequestration and soil organic matter and reduce pesticides, combined with transformation to renewable energy carriers in situ, e.g. by biogas production, in a circular approach for soil nutrients and carbon. Positive effects on soil biodiversity/soil health and soil functionality as regards increasing soil organic matter, phosphorus and other nutrients and reducing the risk on groundwater contamination from nitrogen oxides should be assessed. Solutions should improve the cost-effectiveness and the sustainability (including biodiversity) of agricultural waste and land management through valorisation of wastes and secondary crops based on renewable energy technologies.

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.

Energy systems, grids and storage

The integration of renewables in an efficient way that ensures cost-effectiveness and affordability, security of supply and grid stability depends on efficient and effective network management. Real time monitoring and optimisation are necessary to increase the flexibility, through solutions such as storage, demand response or flexible generation among others, to integrate higher shares of variable renewable energy. Exploiting synergies between electricity, heating and cooling networks, gas networks, transport infrastructure and digital infrastructure will be crucial for enabling the smart, integrated, flexible, green and sustainable operation of the relevant infrastructures. Besides hydrogen and batteries that are addressed elsewhere, R&I in other storage technologies, in particular thermsal storage but also electrochemical, chemical, mechanical and electrical storage solutions is necessary to create a set of flexibility options.

In line with the “Orientations toward the Horizon Europe Strategic Plan” and with the directions of the Strategic Plan, the impacts and topics in the area on “Energy systems, grids and storage” will be synergic with and complementary to those developed in other areas or sub-areas of the strategic plan, as the areas of batteries, of hydrogen and of RES. Precisely, the “Energy Systems, grids and storage” area will primarily focus on the systemic aspects to enhance the flexibility and resilience of the system, in particular: integrated energy system planning and operation, engaging consumers and providing new services, electricity system reliability and resilience, storage development and integration and green digitalisation of the energy system.

Batteries and hydrogen are the focus of other relevant sub-areas of the strategic plan and will be here considered in the broader framework of storage integration, flexibility and grids services. With regard to the integration of renewables, elements of specific RES technologies allowing an easy integration of diverse renewable energy source will primarily be the addressed in the RES sub-area.

Moreover, the role of citizens and communities is key when it comes to making the flexibility at appliance level available for the grid. Related to this, the inclusion of social sciences and humanities (SSH) where relevant is essential to build the social acceptance of new energy technologies and increase participation of consumers in energy markets.

All projects will contribute to an increased capacity of the system to integrate renewable energy sources and less curtailment at transmission and distribution level. The main expected impacts are:

- Increased resilience of the energy system based on improved and/or new technologies to control the system so as to maintain system stability and continue activities with critical loads in situations of emergency and partial failure and the ability to reduce the effects of major catastrophic events.
- Increased flexibility and resilience of the energy system based on technologies and tools 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. This includes an increased availability of tools for network operators, regulators and stakeholders to compare the potential of local flexibility options with grid reinforcement.
- An increasing range of possibilities that is made available to consumers to benefit from data-driven energy services, and possibilities for consumers to invest or engage in the energy transition, through self-consumption, demand response or joint investments in renewables. This, either individcually or through energy communities or micro-grids, in a way that enhances consumer satisfaction and contributes to an increased level of flexibility of the energy system;
- Demonstrated energy storage technologies, in particular heat storage but also others such as electrochemical, chemical, mechanical and electrical;
- Higher degree of interoperability, increased data availability and easier data exchange among energy companies as well as companies using energy system data to develop new services and products, to support an EU market for new energy services and business models as well as tested standardised and open interfaces of energy devices;
- Demonstrated new electricity transmission technologies to enhance its efficient operation, 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 for transporting off-shore energy.

The list is not exhaustive, and in the frame of the rapid development of modern integrated and sustainable energy services, more and more new impacts can be expected, to be evaluated during the progress to be made in the area in the next years.

C5-D3-ESGS-01-2021: Energy Sector Integration: Integrating and combining energy systems to a cost-optimised and flexible energy system of systems

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 9 million and EUR10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and

	selection of a proposal requesting different amounts.
Type of action	Innovation actions
Technology or societal readiness level	Activities are expected to achieve TRL 6-8 by the end of the project – see General Annex D.

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

- Demonstrated benefits of sector integration in different geographic, climate and economic conditions
- Preparatory and study aspects of integration of power, heat, gas, industry with a production site(s) of renewable energy.
- Optimised dynamics of coupled networks (e.g. electricity vs. heating)
- Validated tools and platforms enabling effective sector coupling as tested in large demonstration projects.
- Consolidated methodology to evaluate the impacts on OPEX, CAPEX and overall value creation connected to the integration of flexibility from storage and other energy flexibility solutions.

<u>Scope:</u>

Projects should demonstrate the benefits of the integration of different elements. This includes in particular electricity and gas networks, district heating and cooling, and long term energy storage systems (for example Hydrogen, power-to-X, thermal storage, hydro-storage). It can also include mobility systems (e.g. e-mobility infrastructure) and energy-intensive industry and/or industrial clusters or sites. Projects should demonstrate the integration at local (i.e. distribution networks) and at national level (i.e. transmission networks), and the interactions between them.

- Develop 2 or 3 pilots in different Member States that demonstrate of solutions for energy system integration based on integrated management of various networks and infrastructures. This can include the possibility to, including for example:
    - Electricity and gas networks
    - Implementation of solutions for district heating and cooling as sector integration for energy storage and flexible operation at different energy levels and carriers;
    - E-mobility infrastructure;
    - Solutions for industry and industrial clusters for integrated flexible generation, consumption and energy storage.
    - Flexible stand-alone systems and tools for living quarters and small and medium sized businesses and industries based on renewable generation, sector-coupling and storage technologies
    - use integrated systems to allow for long term (weekly, seasonal) energy storage
- Demonstrations can be build up based on a combination and integration of various locally optimised grids into overall system management.

Projects should provide preliminarly a gap analysis, considering country-specific challenges and a sustainability assessment for the environmental impact, social acceptance and impact as well as economic feasibility.

The participation of inter- and trans-disciplinary consortia combining expertise and capacity from public authorities, urban stakeholders, infrastructure providers, knowledge institutions, planners, entrepreneurs, societal actors and citizens is necessary to address the challenges of this topic.

Projects should develop a consolidated methodology to evaluate dynamics of coupled networks and the impact on OPEX and CAPEX connected to the integration of flexibility from storage and other energy vectors as well as build upon integrating knowledge on cost reduction for the relevant conversion processes.

Projects should develop tools for:

- Assessment of technical and operational challenges, including environmental impact and social acceptance.
- System planning toolboxes to determine the optimal sizing, location and distribution of energy storage systems and technologies to facilitate their optimal use at different grid levels, as well as system planning toolboxes to determine the optimal location and utilisation rate of energy conversion plants available.
- Aging models' definitions for several storage technologies according to the operating conditions and required regulation services.
- Communication, platforms and devices for increased observability/controllability of the generation, consumption and storage resources and the measurement acquisition.
- Tools to quantify the flexibility provided by sector integration.

Where relevant, projects must collaborate with the Clean Hydrogen Joint Undertaking on aspects that require integration of hydrogen.

Activities in relation to **production of hydrogen are excluded,** as all production aspects are treated through the calls of the Clean Hydrogen Joint Undertaking. **Fuel Cell Micro Boilers** technology is also **excluded** due to technology development through the Fuel Cell Joint Undertaking. Cooperation with the Joint Undertaking, for example through joint projects, is however welcome.

The selected projects are expected to contribute to relevant BRIDGE[34] activities.

C5-D3-ESGS-02-2022: Energy system modelling, optimisation and planning tools

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of up to EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting

[34] https://www.h2020-bridge.eu/

	different amounts.
Type of action	Research and Innovation Action

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Provide local, regional, national and European public authorities and network operators, with customisable open source models of the components of the energy system, as well as tools to assemble these component models into a model of the energy system integrating the infrastructure related to all energy carriers in a given geographical area, with static and dynamic (transient) modelling capabilities;
- Provide local, regional, national and European public authorities and network operators, with an open source tool to allow them to better plan and optimise the development of renewable energy sources and the enhancement of infrastructure (including storage) to meet the future energy needs in a geographical area, while minimising the total investment and operation cost, hence satisfying the future final uses of energy (or feedstock) of consumers, at lowest cost and with better predictability
- Enable the transition to carbon-neutrality and the competitiveness of industry, through the integration of renewable and low-carbon energy sources at lowest cost
- Validation of the tool in two real-life cases: one industrial cluster and one region

Scope:

Advanced modelling tools to perform cross-border and cross-energy vector reliability-of-supply assessments on a long time horizon, where cross-sectoral disruptive innovations in industry, mobility and building sector can be included

Building on existing open source models as far as they are available, the project should further develop and validate an open source model of the components of the energy system and provide tools to integrate these component models into a **system model** to satisfy the (future) needs in a geographical area, thereby providing a planning tool for cost and emissions optimisation **of the enhanced energy system at pan-European level**. The aim is to better plan and optimise the expansion of the energy generation and transmission and storage systems to meet the (future) energy needs aggregated at a granularity level finer or equal to the NUTS2 level; the distribution layer to individual energy users is not to be considered.

The open source modelling tool should be composed of the most relevant of the following modules:

The multi-physics **component models** must model the cost (CAPEX, fixed and variable OPEX, economic lifetime) and technical performances (including GHG emissions) of the components, they must be parametrised to take into account the local climate and socio-economic characteristics of the geographical area where they will be located, as well as the time-dimension, such as the season and time of day. The component models must be capable of dynamic modelling with appropriate time steps (e.g. quarterly or hourly power profile of sources for intraday balance assessment; weekly or monthly profile for seasonal balance). The component models must be described with standard modelling languages and be modular, so that each one can be updated without impact on the others and can be assembled with other models. They should cover:

- **Renewable energy sources**: energy production units of several typical sizes, covering technologies, such as for example photovoltaic, concentrated solar power, solar thermal, geothermal, onshore wind, offshore wind, hydroelectric, tidal, wave, biogas, biomass … Modelling of their cost, emissions, typical (average) production performance of the sources, taking into account (where applicable): the season (month of the year), time (hour of the day), geo-location (at NUTS-2 level), and other parameters that can affect cost/performance. Where applicable, the statistic variability of their performance should be given and power profiles should be generated, for running dynamic simulations when the component modules will be integrated into system modules. A large-scale source should have its own model, small-scale sources (such for example wind turbines or household PV) should be aggregated (e.g. households PV aggregated at the level of a city).

- **Non-renewable primary energy sources** (natural gas, coal, oil, uranium …): extraction, import; modelling of the production cost, capacity, GHG emissions and geolocation
- **Non-renewable energy conversion**: refineries producing fuels or hydrogen; modelling the cost and performance (including GHG emissions) of the conversion from the primary energy carrier to secondary energy carriers, including CCS where applicable)
- **Non-renewable electricity production** (coal, natural gas, oil, nuclear …) – cost and performance of existing or new power plants, including CCS where applicable; modelling the transformation from the primary energy carrier to electricity (including GHG emissions)
- **Renewable energy conversion**: production of hydrogen (green and blue) and other renewable or low-carbon gaseous or liquid fuels; modelling of their cost and performances (power, efficiency …); modelling the conversion from the primary energy carrier (and feedstock) to secondary energy carrier and by-products (O2, CO2, including GHG emissions …)
- **Energy storage** models: stationary batteries (large scale and house), electric vehicle batteries, hydropower storage, thermal storage, methane storage, hydrogen storage … ; modelling of their cost and performances: power, efficiency, capacity, life expectancy, state-of-charge (for dynamic modelling), life cycle GHG emissions
- **Transport pipelines** (including recompression stations): cost (per km) and performance (capacity, efficiency, GHG emissions) of existing and new natural gas, hydrogen, CO2 pipelines, district heating/cooling pipelines or of upgrading pipelines to admixtures of renewable gasses or to pure hydrogen or to CO2; as well as **other infrastructure (e.g. LNG terminals) or logistics** (e.g. transport by ship)
- **Transmission power lines**: cost (per km) and performance (capacity, efficiency), of existing or new power lines, or for upgrading existing power lines to higher voltage/capacity
- **Energy consumers**: modelling of the energy use profile of typical active consumers (industry, buildings, households, local heat networks, mobility and transport) for the different types of energy carriers, taking into account (where applicable): the season (month of the year, and associated average temperature), time (hour of the day), geo-location (at NUTS-2 level), and other parameters that can affect their energy use. Where applicable, the statistic variability of their performance should be given, for running stochastic simulations when the component modules will be integrated into system modules. Where applicable, their capability to shift their consumption in time (demand response) and to store energy should be modelled, including the cost of this

flexibility service. A large-scale user should have its own model; small-scale users, such for example household or eVehicle and (bi-directional) charging or refuelling stations, should be aggregated at the level of a city or NUTS2 region.
New methods to take into accounts new types of assets connected to the grids (Electric Vehicles (EV), microgrids, storage, small scale production, non-synchronous generators, etc.) and considering the cost-effective coupling with other energy networks.

System modelling, planning and optimisation tool:

- A **system modelling tool** must be developed to integrate the models of the components located in a geographical area into a system model. The models will use the data on the future needs of industry and other end-user sectors. The system modelling tool must allow both static and dynamic simulations, to assess the intraday, weekly and seasonal balances and associated transient stability. The modelling tool has to be modular and open to ensure coupling with other models, for example models including the exchange of resources and materials (enabling industrial-urban symbiosis and circularity), as well as socio-economic and market models.
- Based on the system model, an **optimisation and medium-long term grid planning tool** must be developed to optimise the development pathways for renewable energy and other low carbon sources, storage and the enhancement of infrastructure, to meet the future energy needs in a geographical area, while minimising the total investment and operation cost, hence satisfying the future final uses of energy (or feedstock) of consumers, at lowest cost and with better predictability.
- **Visualisation tools** must be developed to support the system modelling, the optimisation process and their results, notably in the format of dynamic energy heat maps. The compatibility of the results format with the JRC visualisation tools should be ensured.

Validation of the models and tools:

- Methodologies and procedures must be designed for the **certification** of the component and system models
- The component models, system modelling and optimisation tools must be **validated** by using them in support of the planning of the energy transition of two real-life geographical areas: one macro-region (e.g. several small or large countries) and one large (possibly cross-border) industrial cluster. The validations should cover the range of models and tools developed, and should therefore include in particular the dynamic modelling of relevant energy sources (intermittent and dispatchable), different existing or new energy networks, conversion between different energy vectors, energy storage and energy consumers capable of demand response.

The component models and the system modelling/optimisation tools must be a properly **documented and open source** development allowing the EC, the Member States and Associated States and other public authorities or private organisations to use the tools for their planning needs, or to develop additional add on modules. The models and tools, as well as the relevant documentation and user guides, must be published under an appropriate open license and made available to the modelling community on the Energy Modelling Platform for Europe[35]. The results of the project should be **disseminated**, notably at the EMP-E annual conference. Upon completion of the projects presently supporting the EMP-E platform and conference, the selected project should take over supporting the platform and organising the annual conference.

The research will entail interviews with key asset operators and public administrations in all 27 EU Member States, so as to inform collect their views how the tools could best meet their needs. At least 2 interviews per MS should be foreseen.

The development of the models, simulation, optimisation and visualisation tools will be closely coordinated with DG Energy, DG Research and Innovation and with the Joint Research Centre.

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-03-2022: Supporting the action of consumers in the energy market and guide them to act as prosumers, communities and other active forms of active participation in the energy activities

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution between EUR 5 and 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 6-8 by the end of the project – see General Annex D.

<u>Expected Outcomes</u>: Project results are expected to contribute to most of the following expected outcomes:

- Demonstrate in real life interactive communication and support tools to engage citizens in the energy transition and to support them throughout the process of creating, constituting and developing an energy community, that are developed and fine-tuned based on field-tests;
- Optimal engagement (tariff design) of distributed active consumers and energy communities at massive scale, including through innovative incentive mechanisms;
- Enabled new market roles, market participants and energy communities;
- Enabled automated participation

[35] http://www.energymodellingplatform.eu/

- residential and SME related Demand Response contributing to increased level of flexibility and to the development of new flexibility products;
- Identified drivers and rules beyond marginal pricing which can steer the transactions within the energy communities.
- Capacity building of energy community members and support to organisations providing it;

Scope:

The provisions of the Clean Energy Package have paved the way for a new, more active role of prosumers and energy communities in the electricity market. Innovative tools and tailored solutions should be developed and tested in order to fully enable new type of interactions between citizens as consumers, prosumers and (members of) energy communities and foster participation in energy (in particular electricity) markets.

To this aim, projects should link citizens, technologies, regulation and markets together.

Developing mechanisms to support the creation, growth and capacity building of energy communities.

Tools should be developed to support demonstration of the energy community paradigm shift within the mentioned context using suitable digital platforms for putting the citizens in direct contact with each other, suppliers, aggregators and other involved market stakeholders and to increase prosumers' satisfaction and participation.

Dedicated demonstrations should be set to demonstrate the use of these interactive tools to contribute to real-time optimization of Distributed Energy Resources and the facilitation of investment decisions at household or community level in RES or demand response.

To get the acceptance of different energy technologies in civil society, these demonstrations should be build on SSH approach to take into account the social and behavioural dimension at the stage of their design.

As a result, these demonstrations shall aim to increase the understanding of consumer's behaviour (e.g. by providing direct action on demanding asset as close as possible to real-time). They should also aim to crceate innovative tools and tailored solutions to empower prosumers, to help them to realise energy communities and finally pave the way for the true energy transition.

With these new insights the projects are expected to adapt the solution, test it again and compare the outcome of both approaches.

The tested solutions should be able to reconciling the top-down market developments with the bottom-up changes in the market arrangement and participation.

Solutions are expected to be as replicable as possible and to be demonstrated in a variety of geographical locations in different member states representing very different social and economic situations. In addition, regulatory / administrative barriers and possible solutions should be assessed as part of the projects.

To do so, projects are expected to design, develop and test incentives for market participants to react to system conditions according to location and time while also investigating optimised economic solutions for prosumers.

Projects should develop the entire functional chain from data collection and elaboration, to local flexibility needs and user-centric compensation enabling the active participation of prosumers.

Projects shall take into account related ongoing activities under H2020 and Horizon Europe and are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-04-2021: Increasing energy system flexibility based on sector-integration services to consumers (that benefits system management by DSOs and TSOs)

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of 9 EUR and 10 EUR million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex D.

Expected Outcomes: Projects are expected to contribute to most of the following outcomes:

- New business models for market parties based on energy services and revenue streams for consumers (across energy sectors and beyond, based on valorisation of the flexibility in their energy consumption);
- Enable market parties to provide flexibility services to network operators and the wholesale market based on competitive markets that are easily accessible and at low transaction costs;
- Increased application of digital technologies to support consumers and market parties to market their flexibility;
- Increased consumer engagement and acceptance.
- Increased availability of flexibility sources for TSOs and DSOs and enable them to develop markets for flexibility and interact with many distributed resources at the same time (via intermediaries such as energy suppliers or aggregators) based on seamless data exchange and interoperability;
- Facilitate scaling up the platforms and markets to spread its use by making it as easy as possible for suppliers, aggregators or consumers directly to offer grid services based on other or new small-scale and large-scale assets/devices on these markets, if necessary through as easy and automated pre-qualification processes as possible;
- Better understanding of market models and regulatory measures that can promote new business models;
- Contribution to better informed investment decisions by network operators and tariff setting models by NRAs, as flexibility markets and new business models can postpone or avoid new investments making better use of existing assets.

Scope:

The projects will test and develop further already demonstrated solutions for data-driven energy services for consumers, in cooperation with various actors in the energy system (such as prosumers, aggregators, TSOs, DSOs, owners of assets that can provide flexibility like batteries, heating/cooling systems, charging point operators, gas systems):

- Replicate them in as many different geographies as possible having different system needs, consumer needs, economic conditions or different climates. They will be adapted to the local energy requirements and they will aim at increasing consumer acceptance and participation. Focus is expected to be in the facilitation of different services.
- Integrate energy services with other services for citizens and/or consumers (e.g. health, safety, mobility):
  - focus on business models that combine energy services with other services, such as health, security, home automation or mobility servicesm taking into account experiences and practice from social science and humanities;
  - focus on business models for households that combine energy services focused on flexibility with investments in assets at consumer level that contribute to long-term changes in electricity production or consumption, such as RES generation, energy storage, deep renovations, new, more efficient and intelligent appliances that form a major part of household energy consumption (e.g. heating);

The development and testing of business models will contribute to a better understanding of the ways to promote such models and to address their impact in the design, modelling and planning of energy markets at all time scales and at all geographical scales, from the pan-European cross-border wholesale electricity and gas markets, products, services and businesses, down to local, neighbourhood, aggregated, retail, peer-to-peer market of energy products and services (flexibility, ancillary services, electricity, gas and heating/cooling).

The solutions are expected to be aligned with already existing markets. The projects will therefore be asked to cooperate to jointly provide detailed analyses and studies that address possible regulatory measures related to the implementation of the Clean Energy for All Europeans Package.

Specific demonstrators will make use of operational end-to-end architectures, digital platforms and other data exchange infrastructure 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 activities.

C5-D3-ESGS-05-2021: Reliability and resilience of the grid: Measures for cybersecurity, vulnerabilities, failures, risks and privacy

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 7 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex D.

Expected Outcomes: Project results are expected to contribute to the following expected outcome.

Demonstration of increased energy system reliability and resilience following disturbances, faults, cyberattacks, terrorism, etc. at all relevant levels (infrastructure, hardware, software, organisational, etc.).

Scope:

Obligatory (all): proposals shall include

- Demonstration of measures to minimize TSO and DSO risks, vulnerabilities and priority strategies and measures against nature and man-made hazards, terrorism, weather, migration, etc. for:
    - substation systems security and design;
    - HV, MV, LV grid infrastructures including platforms for TSO and DSO interaction
    - automatic control of decentralized flexibility solutions ;
    - Events resulting in cascading failures, their mitigation and prevention.
- Application of advanced information technologies (e.g. probabilistic safety assessment, quantitative risk analysis) in system development, operation and asset management.
- Application of digital technologies for ensuring operational data quality and demand patterns recognition for data access and information acquisition to maintenance operators.
- Develop shared knowledge basis within European area concerning threats, vulnerabilities, methods, not only for components but for entire systems and energy system technologies.

Optional (at least two): proposals should include

- Development and application of block chain technology for the identification and authentication of energy IoT devices, authentication of origin in spare part management, trading certificate infrastructures, protection relay configuration and micro grid management.
- Develop, test and demonstrate advanced intrusion detection and prevention systems for energy infrastructures including security-related data and deep learning methods.
- Dedicated strategies for enhanced security and resilience at DSO and TSO level, including TSO/DSO security data sharing should be demonstrated
- Develop and apply methodologies for automation of grid maintenance (for example through robotics), advanced human-machine interfaces, and of data validation processes automation by applying emerging technologies.

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-06-2021: Electricity system reliability and resilience by design: HVDC-based systems and solutions

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of EUR 7 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex D.

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

- HVDC technologies contribution to the deep decarbonisation of the electricity generation sector allowing the integration of large share of renewables while concurrently addressing the security of supply.
- HVDC interconnections can act as a firewall blocking the spread of disturbances while permitting the interchange of power.
- Mastering HVDC technologies will open new business horizons for European companies in the global clean energy markets.
- Increased electricity system reliability and resilience throughout the overall interconnection system, which includes High Voltage cables. Furthermore, the use of buried HVDC cables reduces the visual impact and improves the social acceptance compared to the classical AC overhead lines.

Scope:

Proposals will explore concepts and propose solutions to foster the development of large HVDC based transmission grid infrastructures, able to bring benefits to the existing electrical system and capable of integrating the fore coming large amount of renewable energy.

Proposals should demonstrate the reliability and resilience of the energy system through HVDC interconnections integrated in the AC grid while coping with faster dynamics,

in particular by addressing the following:

- Proposals of optimal grid architecture concepts and related demonstrated advantages, with a careful overview of planning aspects and deployment methodologies. Proposals should investigate and identify the technological, contractual and regulatory barriers for the deployment and present solutions to remove them.
- Real-time monitoring and assessment of the level of system stability and vulnerability against disturbances of future AC systems characterised by more HVDC and less conventional power generation.
- Reliability model for HVDC and its impact on the overall transmission system reliability with the HVDC link acting as ‘firewall ‘within the synchronous AC transmission system.
- Technical-economic benefits of the HVDC interconnection solution with the “firewall” functionality as well as in combination of other advantages contributing to the system security such as relieving heavily loaded AC corridors, etc.

- Simulation, real time demonstration of the avoidance or containment of cascading effects and resilience to cyberattacks or faults of the HVDC connection in the AC network.
- Simulation, real time demonstration of the co-ordinated use of HVDC-connected RES for containment of cascading faults and contribution to system restoration.
- Evaluation of the impact on system reliability of an increasing number of HVDC links incorporated in the transmission system through modelling and quantification of the dynamic "firewall" properties of the HVDC links incorporated in the transmission system.
- Evaluation of the use of HVAC fault location and monitoring systems for cables in HVDC (e.g. fibre optic distributed temperature sensing, online PD detection and location and time domain reflectometer (TDR) measurements for faults pre-location and fingerprinting).
- Development of novel pre-fault monitoring systems for the evaluation of the actual status of the HVDC cables and accessories, with the aim to improve the reliability of the DC links.
- Development and validation of new dielectric materials for the insulation of HVDC cables and accessories aiming at achieving higher capacity transfer capabilities. The proposed materials should have reduced ageing due to space charge accumulation phenomena.
- Proposals for highly reliable design and manufacturing of HVDC cables and accessories and related demonstrated advantages. Proposals should investigate the sustainability of the identified procedures through LCA.

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-07-2021: Demonstration of superconducting systems and elpipes (in support of the offshore strategy)

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of around EUR 15 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	The objective is to extend the effective range/scale and to bring long distance DC Superconductors to TRL 8 in Europe

<u>Expected Outcomes</u>:

The Superconducting Transmission Lines (SCTL) main advantages are higher transmission efficiency and ability to use lower operating voltages while still preserving the total capacity. Potential applications for transport of high amounts of energy or in EU congested grid context is then key for the development of the grid and to increase its efficiency.

Elpipes are polymer-insulated underground HVDC conductors based on low cost extruded metal conductors. The technology could potentially be used to transfer massive capacities in identified corridors. An elpipe installed at the surface could go to at least 30 GW with passive cooling. Actively (but non-cryogenically) cooled elpipe designs can theoretically go to transfer capacities above 200 GW.

Project results are expected to contribute to [all/some] of the following expected outcomes:

- New SCTL technologies to upgrade and expand the electric grid to meet the requirements imposed by the increasing penetration of renewables
- Increased power transfer capability within existing right of ways,
- Test and validate the transmission of bulk power not achievable with current cable technologies.
- Investigate the feasibility and applicability of elpipes for high transfer rates in identified corridors
- Use of different superconductor technologies (e.g. HTS, MgB_2) with different cooling medium, power rating and lengths.

Scope: The activities will concur to demonstrate the reliability of the technology and its applicability in the grid network.

- Demonstration of up to ±100kV, up to 1 GW power, superconducting system (HTS) up to 5 km onshore
- Demonstration of ±100 kV, up to 1 GW power power, superconducting system up to 100 km, offshore.
- Demonstration of a SCTL based on MgB_2 LH_2 cooled, for DC with a length up to 1 km and above onshore. The voltage level and the cable section shall be designed to have the maximum benefits in terms of insulation requirements and conductor section for a capacity transfer of 10 kA and above.
- Cable design and simulation of kA range faults, power reversal response, loss calculation and demonstration for protections of SCTL.
- Technical-economic benefits of the SCTL demonstrated compared with traditional (overhead lines, XLPE cable)
- Investigate the feasibility and applicability of elpipes with technical economic analysis, use cases, etc.

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-08-2021: Demonstration of advanced Power Electronics for application in the energy sector

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action

Technology or societal readiness level	Activities are expected to achieve TRL 5-6.

Expected Outcomes:

Wide Bandgap-based (WBG) such as Silicon Carbide (SiC) semiconductors enable higher power density, operation voltages, temperatures, and frequencies while reducing heat dissipation of the PE. This enables the development of more efficient and smaller size converter stations affecting considerably on grid distribution generally and logistics, cost, etc. and the deployment of the offshore energy grid. Right now SiC allows for sufficient reduction on converter footprint, but it is far too expensive, and its cost has a negative impact on overall system cost.

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

- Production, test and validation of WBG-based switching semiconductors such as Silicon Carbide (SiC) for HVDC – MVDC converter applications in converter stations.
- Reduced size of components and equipment for offshore / onshore applications.
- Reduced cost of WBG-based semiconductors such as Silicon Carbide (SiC)

Scope:

The activities are intended to produce, test and validate WBG-based based switching semiconductors such as Silicon Carbide (SiC) for converter station application. These include, but are not limited to:

- Production of SiC based semiconductors for HVDC – MVDC converter applications (example for HVDC: MMC cells with SiC 3.3 kV and above, 1,5 kA and above with optimal increased switching frequency to reduce losses).
- Converter board design and production (power and control parts installation and soldering of all components, hardware and software testing, etc.).
- Simulation and analysis of the impact of the actual passive components used in WBG components circuitry in the above mentioned conditions; development of strategies and innovative techniques to upgrade them for better adaptation to the afore-mentioned working conditions.
- Analysis of the impact of fast transients from power electronics on other electrical components that were not originally designed to endure such stresses.
- Series modules assembly for converter application.
- Simulation and real time testing and validation of the converter with WBG-based switching semiconductor.
- Technical-economic assessment of the benefits provided by WBG-based compared to Silicon-based switching semiconductor of converters.

The action involves the collaboration DG ENER – ECSEL.

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-09-2021: Laying down the basis for the demonstration of a Real Time Demonstrator of Multi-Vendor Multi-Terminal HVDC with Grid Forming Capability: Coordinated action

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of EUR 1 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

Expected Outcomes:

The call is intended to support all the preparatory phases among all stakeholders (HVDC systems manufacturers, TSOs, wind turbine manufacturers and windfarm developers) leading to a demonstration project to de-risk the technology to enable the installation in Europe of the first Multi-Vendor Multi-Terminal HVDC system with Grid Forming Capability. The HVDC system should guarantee at least the technological capabilities needed for advanced grid management capabilities and the deployment of the offshore grid (active and reactive power controlled separately, support to weak AC grids, black start, etc.). HVDC systems are applicable and can be planned, designed and integrated in any part of the AC grid, i.e. onshore as well as offshore. Following the Commission adoption of the "Strategy on Offshore Renewable Energy", attention is presently focused to offshore grid application.

The demonstration project deriving from the CSA will pave the way to the deployment of the offshore energy system, which will enable the integration of increasing amounts of RES in the energy system.

Project results are expected to contribute to [all/some] of the following expected outcomes:

- Solid foundation to ensure investments in DC technologies for the EU electricity network needed for the energy transition.
- Agreement among stakeholders (HVDC systems manufacturers, TSO, Regulators, Standardisation bodies, wind turbine manufacturers, windfarm developers etc.) and planning for the demonstration of a Real Time Demonstrator of Multi-Vendor Multi-Terminal HVDC with Grid Forming Capability, which will lead to the first real-life full scale installation in Europe.
- New way of framing the EU energy system (on- off-shore) architecture and topology.
- Provide new pathways to offshore energy and development.

Scope:

The coordinated action supports all the multiple preparatory tasks, which will lead to a global agreement among stakeholders and define the detailed planning for the full scale industrial demonstrator. These include, but are not limited to:

- Coordination and organization of a platform involving all stakeholders (HVDC system manufacturers, TSOs, third-party HVDC system integrators, wind turbine manufacturers, offshore wind farm developers).
- Compatibility of modelling tools towards interoperability.
- Model sharing between TSOs: legal framework.

- Roles and responsibilities on interoperability issues.

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-10-2022: Real Time Demonstrator of Multi-Vendor Multi-Terminal HVDC with Grid Forming Capability (in support of the offshore strategy)

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of EUR 55 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7-8.

Expected Outcomes: Project results are expected to contribute to the following expected outcomes:

- Real Time Demonstrator of a Multi-Vendor Multi-Terminal HVDC (High Voltage Direct Current) with Grid Forming Capability to de-risk the technology and pave the way to the installation of the first installation in Europe of a Multi-Vendor Multi-Terminal HVDC system with Grid Forming capability. The Grid Forming capability in the demonstrator addresses the loss of inertia that the grid will incur with the huge integration of offshore RES.
- New way of framing the EU energy system (on- off-shore) architecture and topology.
- Way opening to the offshore energy development. Provide new pathways to offshore energy and grid development
- Involvment, best practice and acquired experience and confidence of all stakeholders (HVDC system manufacturers, TSOs, third-party HVDC system integrators, wind turbine manufacturers, offshore wind farm developers).

Scope:

The real-time demonstrator is the preliminary step to de-risk the technology and enable a real life demonstrator application, which will pave the way to the exploitation of the offshore RES and the development of the offshore grid. Proposals will include all the necessary activities concurring to the implementation of a Real Time Demonstrator of a Multi-Vendor Multi-Terminal HVDC (Voltage Source Converter High Voltage Direct Current) with Grid Forming capability. HVDC systems are applicable and can be planned, designed and integrated in any part of the AC grid, i.e. onshore as well as offshore. Following the Commission's adoption of the "Strategy on Offshore Renewable Energy", attention is presently focused to offshore grid application. The HVDC system will guarantee at least the following capabilities or better:

- Independent and full control over the active and reactive power;
- Provide support to weak AC systems;
- Power flow reversal without the need of reversing the voltage polarities;
- Excellent response to AC faults;

- Black start capabilities.

These include, but are not limited to:

- Requirements for multi-vendor converter capabilities in all connection points (AC side, DC side).
- Definition of basic and detailed functional specifications, control and protection interoperability, readiness for future seamless system extension, standardization of HVDC models and replicas, model for interoperability assessment of grid forming converters, etc.).
- Definition of basic and detailed functional specifications, control and protection interoperability, and standardisation of wind power plant models and replicas for assessment of integration to HVDC grids.
- Development, integration, testing and validation of HV components and sub-systems guaranteeing interoperability with functionality. Evaluation of the technological challenges related to placing MT-HVDC systems subsea, e.g. at the sea bottom.
- Real-time physical demonstrator of a HVDC system connected to the AC grid with at least three terminals of three different manufacturers with power rating applicable in the current exisitng real life use cases.
- Contextually, proposals will address grid codes and standardisation issues for all EU operators in close cooperation with DG Energy.
- Regulatory framework analysis, definition and application aspect.

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-11-2022: Interoperable solutions for flexibility services using distributed energy storage

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 2 million and EUR 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-7

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

- A new generation of energy management systems implemented to provide the capability of a hybrid energy storage systems (HESS) to work as a conventional battery energy storage system with enhanced performance. Hybrid energy storage systems can concern distributed sources of storage, such as EV Batteries, Home Batteries, or connection with the Heat Pumps;

- In the first stage, the agreeing in wide scope of stakeholders including EV community and other sources of storage (flexible heat pumps) on a common protocol that could connect different storage applications (Energy- Home management system, heat pumps, EVs).
- Validation of user acceptance, and demonstrating concepts that ensure privacy, liability, security and trust in connected data spaces.
- To encourage EU citizens and businesses, especially SMEs to deploy storage, the ease of use and consequently interoperability are a must.

Scope:

The objective is to develop interoperable distributed storage technology to enable the seamless utilization and monetization of storage flexibility within a real life environment.

Pilot(s) needs to demonstrate Battery Energy Storage Systems (BESS) and Hybrid Energy Storage Systems HESS solutions within the home, building, community and stand-alone and power grid connected together with TSO and/or DSO, including real-time data sharing and operation.

At least 2 pilots, with different use cases (overall covering both BESS and HESS systems), should present interoperable solutions involving different types of BESS.

The project(s) should facilitate HESS reaching a similar interoperability and Plug-and-Play capabilities of a BESS with extended performance by using virtualization techniques.

A new generation of energy management systems implemented ***to*** a hybrid energy storage systems (HESS) ***so it can efficiently perform with the combined capacities of the individual energy storage systems (ESS) that conform it.*** Hybrid energy storage systems can concern distributed sources of storage, such as EV Batteries, Home Batteries, or connection with the Heat Pumps

Real-time data sharing and operation is ensured, through aligning existing standards from the utility and ICT domains, across the devices and systems to enable innovative distributed storage services.

Deployment and adoption of IoT standards and platforms for distributed storage systems (stationary and electric vehicles) in Europe and development of cost-effective and sustainable European distributed storage ecosystems and related business models.

- Access of third parties to the minimum necessary data to perform aggregation functions should be looked at: which type of data could be made available for 3rd parties
- Common solution between different stakeholder gropus and different brands of devices should be looke at (for example storage from Heat Pumps requires coordination with several brands, so as to come up to a possible cross brands and cross sector solution)
- HESS dimensioning methodology depending on the application and integration conditions, including the selection of different European manufacturers ESS to conform the HESS, connection architecture, and control. Aspects of competition to be considered (include different manufacturers)
- Validation of the HESS integration in a real environment, demonstrating an efficient energy management, and the benefits of the combined capability of the individual ESS.

- Framework for use of data that may be considered as personal data generated by natural persons under the GDPR

Common architecture models (Smart Grids Architecture Model - SGAM[36]) and implementing standards (such as CEN-CENELEC, SAREF etc.) should be taken into account to ensure interoperability and compatibility.

Highest (semantic) interoperability is reached for all, or most of, use cases of storage and cost of deployment of distributed storage is decreased.

The need for standard harmonization across industry sectors is to be explored, along with legislation and demonstration of scalability and stimulation of spill-over effects, for example towards applications beyond road transport.

Feedback mechanisms from the users should be envisaged to allow adaptation and optimisation of the technological and business approach to the particular use case.. For all actions, the consortia have to involve and/or engage relevant stakeholders and market actors who are committed to adopting/implementing the results.

The selected projects are expected to contribute to relevant BRIDGE activities. Projects should take into account existing interoperability related work of previous and ongoing H2020 and HE research projects such as INTERCONNECT

Collaboration and synergies with the co-programmed European Partnership 2Zero are also expected. Areas will concern interoperable aspects of integration of storage from the EVs, including research on minimum data to be made ready for the third parties (for purpose of storage), e.g. C5-D4-ZERT-08-2021: Pilot project demonstrating system approach for static Smart Charging and C5-D4-ZERT-07-2022 System Approach for advanced Static Smart Charging: integration of EV with the infrastructure of the grid.

Similarly, collaboration and synergies are expected with European Partnership Towards a competitive European industrial battery value chanin for stationary applications and emobility. Areas concern battery management system and operation data (e.g. C5-D2-BAT-12-2021: Physics and data-based battery management for optimised battery utilisation), and complementarities where integration of battery systems into larger systems is not tackled (e.g. C5-D2-BAT-11-2021: Next generation technologies for High-performance and safe-by-design battery systems for transport and mobile applications), will also be expected.

C5-D3-ESGS-12-2021: Thermal energy storage solutions

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution between EUR 7 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	IA

[36] https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf

Technology or societal readiness level	Activities are expected to achieve TRL 6

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

- Develop and demonstrate modular, compact, high performances, thermal energy storage solutions for heating, hot tap water and cooling for electricity load shifting. The integration of the solution within the energy networks of the building and its system management should allow different functions: peak load reduction, energy saving, energy cost minimization;
- Develop and demonstrate a novel thermal energy storage system much more compact than state-of-the-art technologies, enabling the storage of heat and cold for domestic applications for periods typically of 4 weeks long.

<u>Scope</u>:

The scope covers the whole spectrum of application of the thermal energy storage systems, ranging from short run to longer run, as well as from the smaller to bigger sizes:

- Thermal end-uses (space heating, hot tap water, cooling) represent a major share of the EU electricity demand with consumption often at peak times. Integration into the building heating system and in the smart electricity grid is a key development aspect, next to the storage materials and technologies. Such storage devices reduces the demand for electricity from the grid at peak times during the day, allowing off peak electricity to be used in the building for satisfying cooling needs during summer and/or heating demand, for space heating and hot tap water at later times. The typical charging power is in the order of 3 kW, for periods of up to three hours. The TES system is conceived modularly. The high volumetric energy density is a basic requirement given its utilization.
- For buildings not connected to district heating and cooling network, a much more compact TES system is needed to optimize and to increase the integration of varying RES . Such systems need much less volume than state-of-the-art technologies, realized with materials that have extremely low heat losses and enable the storage of heat and cold for domestic applications for periods typically up to 4 weeks. *Cost reduction* is a very important target, as the present solutions are too expensive. The ideal thermochemical TES process should have high reaction heat; Good reversibility; Fast charging and discharging rates; Stable reaction products; Non-toxic, non-corrosive, non-flammable and non-explosive reactants and products; Large-scale availabilities and abundance, affordable price.

The nature of the activities concerns:

- The development of novel phase change materials (PCM) and components (Polymer liners, integrated thermal storage materials, low cost vacuum insulation technology, lid construction) of required characteristics for thermochemical and PCM TES, characterized by low starting TRL (4).

- The development & adaptation of available heat exchanger and novel reactor designs; design and development of controls and modelling for novel sensors for TCM and PCM, starting from a higher TRL (5).
- Ice cold storage having higher TRL (6).

The achievable storage density (kWh/m^3) depends on the technological approach (sensible heat, PCM and TCM) and decreases drastically moving from the component to the system level. Furthermore, with the exception of TCM, the charge of the store decreases with elapsed time. The expected system level storage density measured initially and after four weeks from the charge should be indicated.

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-13-2022: Demonstration of innovative forms of storage and their successful operation and integration into innovative energy systems and grid architectures

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 8 to 9 million for Innovation Actions would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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.

<u>Expected Outcomes</u>: Project results are expected to contribute to most of the following expected outcomes:

- Demonstration of innovative storage technologies which go beyond the state-of-the art of existing storage solutions in respect of sustainability, technical performance, lifetime, non-dependency on location geographical particularities and cost.
- Increased availability, robusteness and safety of sustainable and efficient choices for energy storage to reduce energy losses and improve the environmental footprint of the energy system.
- Demonstrated availability and functionality of innovative energy storage systems developed for specific system designs and applications.
- Improvement of the already established EU storage value chain able to contribute to the EU climate neutrality objectives.
- Creation and improvement of EU technological value chains with the potential for international cooperation and market exploration
- Demonstration of successful business cases and systems designs for energy storage integration solutions in innovative and 'green' energy systems at different scales and timeframes.
- Demonstration of effective integration of innovative energy storage systems and value chains at the interface of renewable energies and specific demand sectors

- Ensuring the compatibility of systems and standards of distributed energy storage for participation in flexibility markets.

Scope:

Demonstration of successful operation and integration of either standalone or combined innovative storage solutions (e.g. chemical, electrical, thermal, mechanical including e.g. compressed air/liquid, supercapacitors, innovative hydropower storage solutions) into innovative energy systems and grid architectures.

Solutions should in particular explore, how innovative storage solutions can enable and drive further the successful penetration of renewable into the European energy mix across several important demand sectors (industry, energy, transport, residential, agriculture) by delivering effectively at the interface of renewable energies and specific demand sector needs.

The 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 demonstrated technologies should respond to energy storage flexibility requirements in form of technological requirements and expected future investment and operational costs and business cases in existing or emerging energy markets, by acknowledging existing system designs and energy grid architectures. The demonstrated technologies should include interfaces for connectin with existing infrastructure, e.g. of hydraulic systems for innovative hydropower or the use of natural gas storage sites for hydrogen or biomethane storage, or abandoned infrastructure such as mines, or storage sulutions in district heating networks.

When integrating the storage solution, common architecture models (Smart Grids Architecture Model - SGAM[37]) and implementing standards (such as CEN-CENELEC, SAREF etc.) should be taken into account to ensure interoperability and compatibility.

Highest interoperability should be reached ideally for most and ideally for alluse cases of storage and cost of deployment of distributed storage should be decreased.

Identified technical and regulatory barriers, also including the market dimension should be addressed. This together with considering consumer acceptance of the solution as a prerequisite to increasing participation of consumers in the energy system when relevant

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-14-2022: Replicable solutions for a cross sector compliant energy ecosystem

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of EUR 8 to 9 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

[37] https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf

Type of action	Innovation Action
Technology or societal Readiness level	Activities are expected to achieve TRL 6-7 by the end of the project

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

- A catalogue of services and flexibility potential of appliances tailor-made for specific consumer groups, as well as the accompanying IT-tools that can help them providing flexibility services to the energy market and system.
- Increase participation of energy consumers in demand side flexibility markets by reducing entry barriers and transaction cost, in particular in relation to data exchange and market access.
- Provide viable interoperable solutions and products, available to all levels of the grid including within the home, which makes it simple to increase flexibility in energy consumption and have a positive impact in balancing demand/response with an increasing share of renewable energy sources.
- Create a vibrant cross-sector ecosystem, successfully mobilising demand-response and demonstrating opportunities for new services provided by SMEs and start-ups.
- Create sustainable marketplaces based on a comprehensive catalogue of energy smart appliances (home appliances including EV charging and distributed energy storage), services and hardware/software solutions compliant with a set of standards for Minimum Interoperability.
- Demonstrate the potential for a sustainable up-take (coordinated across all projects from the call) based on components and solutions piloted in real life.

Scope: Promote the adoption and usage of connected interoperable energy smart home appliances (including the EV charging and storage) and solutions in order to accelerate the deployment of demand-side flexibility services, reduce the entry barrier and facilitate replication.

- Identify a set of open standards for Minimum Interoperability based on the results of multiple research and innovation projects and existing technological developments as well as already available open standards and/or open source solutions to enable energy smart appliances and solutions to participate in demand side flexibility.
- Provide new business models supported by innovative interoperable solutions enabled by connecting systems from different sectors.
- Test interoperable services/solutions based on a reference architecture and minimum interoperability mechanisms that can enable flexibility.
- The solutions initially developed in a pilot in one country will have to be tested, in real life, in at least two other countries, with different energy constraints, by different entities. The overall target is replication in as many Member States as possible.
- Create and populate a commonly agreed catalogue of energy smart home appliances (including EV charging and storage), services and hardware/software solutions compliant to a set of standards for Minimum Interoperability.

- Target entities and/or user: utilities, ESCO/aggregators, appliances manufacturers, energy cooperatives, retailers owning buildings (heating/cooling) in many cities, office building that in their parkings offer eV chargers, waste water treatment plants companies, public buildings, schools, ICT companies, system integrators, Data Centre operators, EV manufacturers, storage providers, industry and other relevant stakeholders with a role in the energy flexibility market.
- The projects should support the proliferation of innovative energy and energy services markets building on interoperable solutions that can be tailored easily to the type or need of users. Therefore the projects should take into account the social and behavioural dimensions of consumer's participation and to get the acceptance of different energy technologies.
- The solutions are expected to adapt digital technologies to the specificities and requirements of the energy system (Artificital Intelligence, Big Data, 5G, cloud/edge computing, Internet of Things ...).
- While complying with cybersecurity requirements privacy issues are to be specifically considered. They have to be built on open architectures and commonly agreed standards derived from these technologies (such as SAREF) and relevant European and Global ICT and Energy Standards Development Organisation and associations
- The selected projects will cooperate among themselves and with other relevant projects through regular common workshops, exchange of non-confidential reports, etc.

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-15-2021: Establish the grounds for a common European energy data space

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of EUR 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal Readiness level	Activities are expected to achieve TRL 5-7 by the end of the project

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

- Higher degree of interoperability between data platforms.
- Energy data made available and re-usable
- Enable new market roles, market participants and energy communities.
- Demonstrated implementations of Energy Data Spaces, exploiting open standards related to data-packages, interfaces, protocols, platforms and procedures
- Enabling new digital solutions and services supporting the energy transition.

- Increased acceptance and participation of consumers on data sharing for energy services.

Scope: Develop, validate, demonstrate and compare different solutions to enable access to and use of energy data through the creation of an Energy Data Space.

- Define interfaces for the exchange of information (i.e. APIs, connectors), and interoperable open standards.
- Pilot innovative solutions for a Common European Energy Data Space[38], to promote a stronger availability and cross-sector sharing of data, in a customer-centric, secure and trustworthy manner.
- Establish a common European Energy Data Space that provides the tools and standards to connects and makes accessible, as much data as possible covering the full energy value chain
- Data spaces should support the ability to accommodate Digital Twins at different levels of the grid and facilitate real-time operations,
- Create a market place for data-driven energy services on top of this energy related data space that are attractive for consumers and operators, increase the potential for investing in green energy and provide innovative services which are not possible w/o these Data Spaces,
- All projects together need to come forward with and test individually the minimum requirements on data governance and data interoperability, where applicable, exploring data source certification schemes..
- All projects together need to demonstrate interoperability of their respective Energy Data Space with those of the other projects in this call. A joint analysis of the solutions is expected as part of this exercise (learnings, best practices, barriers to implementation ...)
- Protection of personal data, cybersecurity and data rights (e.g. right for a fair remuneration) are to be specifically considered, with a final aim to increase the trust of data subjects and data providers in the energy data space.
- Projects should reserve one WP for the activities requiring collaboration, namely demonstration of interoperability, with the other projects of this call.

The selected projects are expected to contribute to relevant BRIDGE activities

C5-D3-ESGS-16-2021: Reinforcing digitalisation related know how of local energy ecosystems

Conditions related to this topic

Expected EU contribution per	The EU estimates that an EU contribution of EUR 4 million would allow these outcomes to be addressed appropriately. Nonetheless, this

[38] https://ec.europa.eu/info/sites/info/files/communication-european-strategy-data-19feb2020_en.pdf

project	does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

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

- Increased autonomy of local ecosystems to participate in the decentralisation of energy systems and energy transition.
- Increase the number of participants in flexibility markets.
- Cover the gap on knowledge around digitalisation of energy services and contribute to the reskilling & upskilling of individuals and organizations.
- Facilitate the creation of a network of parties interested in joining forces for public procurement of energy related digital services.

Scope:

The digitization of the future will not be created only by leading digital technologies, but also by knowledge on and from the application areas of these technologies as well as a range of methods and strategic tools. The creation/reinforcement of local digitalisation-of-energy ecosystems as a way to support a competence cluster for digital energy concepts affecting to operators, consumers/prosumers, and authorities, which enable them being autonomous to react to local energy transition needs.

The project should create an upskilling and reskilling training program, centred on the digitalisation of energy and covering needs of local ecosystems centred on, among others, DSOs, city operators, connected active consumers (energy communities or potential new entrants) and local/regional authorities.

The training program should also contribute to capacity building of energy community members and to the support of citizens in understanding the steps to follow to create an energy community.

The project should seek to establish a cluster organization at local level **for energy relevant** digital technologies such as, but not only, Artificial Intelligence, Internet of Things, cybersecurity, big data, edge computing, data communications or blockchain.

The cluster should bundle a leading digital competences of knowledge and research institutions and companies, including

After identifying the needs and engaging on a local level, the project should provide extensive training in all Member States and make the developed/used training material available as broadly as possible.

The project is open to all type of organisations.

The project should take into account, and collaborate with, where considered necessary, the ongoing EDDIE[39] project from the Erasmus + program, relevant initiatives by Digital

[39] http://www.eddie-erasmus.eu/

Innovation Hubs, EC Digital Education action plan and any other initiative geared in the same direction.

At the same time the project should investigate, and if the reaction is positive, create a network of parties interested in joining forces for public procurement of digital services. One example could be tools for cities to participate in energy flexibility markets that are interoperable, where already present, with their Smart City Platforms)

The selected projects are expected to contribute to relevant BRIDGE activities.

C5-D3-ESGS-17-2021: Interoperability community

Conditions related to this topic

Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

<u>Expected Outcomes</u>:

Project results are expected to contribute to [all/some] of the following expected outcomes:

- Ensure continuity of the ongoing interoperability of energy services related activities.
- Ensure horizontal coordination and support, sustainable up-take of the energy services related to interoperability, data spaces and digital twins.
- Support and disseminate a common framework for testing interoperability across running projects. Harmonise interoperability testing procedures
- Increased interoperability of energy services, data and platforms, both at the function and business layers.

<u>Scope</u>:

Facilitate the coordination and alignment of projects and support interaction between the various related initiatives happening at European and National level.

The project should support a community of practice that includes interoperability expertise relevant to the energy transition.

Keep track of changes in requirements, emerging use cases, regulatory conditions, development of IT/ICT, evolution of relevant standards and all activities impacting interoperability, virtualisation and digital twins, data spaces. Keep track of industrial and working groups' efforts towards interoperability (including ontologies, core models etc.).

Maintain an overview of what is happening, create a repository of best practices & use cases, indicate what is needed to keep this interoperability and provide a forum to support agreements on open standards, convergence on reference architectures and broad dissemination.

Increased interoperability of energy services, data and platforms, both at the function and business layers of the Smart Grid Architecture Model.

Develop an Interoperability Maturity Model (IMM) to indicate the level of maturity in organisations, and the further effort/ actions need to be made to reach higher levels of interoperability.

Create a network of interested parties, and eventually, setting up a distributed European ecosystem of centres for the Interoperability testing of data driven energy solutions. This should take into account existing initiatives like living labs, digital innovation hubs, JRCs Interoperability testing lab related ERANet program calls and Clean Energy Transition Partnership, and should aim at supporting a European knowledge base of use cases, interoperability profiles test cases, and results of tests.

Establishing a cross-fertilisation of existing regional testing infrastructures, explore best practice of local sand-boxing and link with existing networks. Demonstrate with the testing of a set of real life cases where new interoperability requirements are to be tested, how the activities would be organised.

The networks should agree on a common testing methodology and a common test reporting methodology to be used.

The selected projects are expected to contribute to relevant BRIDGE activities.

Carbon capture, utilisation and storage (CCUS)

CCUS will play a crucial role in the EU Green Deal for the transition of energy-intensive industries and the power sector towards climate neutrality. Supporting R&I for CCUS will be particularly important in those industries where other alternatives do not yet exist like the cement industry. This will be highly relevant towards 2050, when most electricity will be coming from renewables, but the need to tackle the process emissions from industry will continue. If CCUS is combined with sustainable biomass, it could create negative emissions.

Low carbon hydrogen from natural gas with CCUS could also play a significant role in industrial climate neutrality, in the transition towards full use of hydrogen from renewable sources, in particular in industries such as steel making, chemicals, or refining where large quantities of hydrogen are needed. CCUS would enable early, clean hydrogen at scale. The hydrogen infrastructure built for clean hydrogen with CCUS could be also shared by hydrogen from renewable sources. It is thus important to develop CCUS for industrial clusters, including aspects of system planning, shared infrastructure solutions such as buffer storage, shared CO_2 and hydrogen transportation and infrastructure optimisation for CCS and CCU.

Demonstration of the full CCUS chain is needed in the EU, with special emphasis on the reduction of the energy penalty and cost of capture and on ascertaining safe storage. Lifting innovative capture technologies from lower to higher TRL should be a priority. Also, the detailed appraisal of cost-effective storage capacity in selected regions, and establishing the necessary infrastructure for CO_2 transport is needed. Solutions for the conversion of captured CO_2 to useful products such as fuels or chemicals will create new markets for innovative industrial sectors and can play a role in supporting the deployment of CCUS.

Under the EU Strategic Energy Technology Plan (SET Plan) ambitious R&I targets have been set in agreement with the sectorial stakeholders. The focus is on CO_2 storage appraisal, cost-reductions, new technologies and proliferation of pilots and demonstrators.

The main expected impacts are:

- Accelerated rollout of infrastructure for CCUS hubs and clusters.
- Updated authoritative body of knowledge on connecting industrial CO2 sources with potential 'bankable storage sites, providing greater confidence for decision makers and investors.
- Proven feasibility of integrating CO2 capture, CO2 storage and CO2 use in industrial facilities. Demonstrating these technologies at industrial scale shall pave the way for subsequent first-of-a-kind industrial projects.
- Reduced cost of carbon capture, which is still the most relevant stumbling block for a wider application of CCUS.
- Establish adequate frameworks for Measurement, Monitoring and Verification (MMV) for storage projects, to document safe storage and for public acceptance of the technology.

C5-D3-CCUS-01-2021: Integration of CCUS in hubs and clusters, including knowledge sharing activities

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 2 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

Expected Outcome: The continuation of investigating CCUS possibilities in hubs and clusters, including knowledge sharing activities, is urgently needed as it could help to identify infrastructure needs. Furthermore, it could also lead to identifying potential new CO2 Projects of Common Interest in the sense of the TEN-E regulation[40]. Early planning will enable and accelerate the roll-out of a CCUS infrastructure consisting of capture points and clusters, intermediate hubs, CO2 conversion facilities, safe and cost-effective CO2 transport and storage. Comprehensive information concerning the integration of CCUS in hubs and clusters shall facilitate the development of operational sites as from the early 2020's. The project will demonstrate the necessary requirements for CCUS integration in carbon-intensive industries and will promote knowledge sharing activities.

Scope: The EU Green Deal underlines that the transition to climate neutrality requires smart infrastructure and defines CCUS among the innovative infrastructures whose deployment in key industrial sectors will be necessary before 2030. Integration of CCUS in high emission industrial hubs and clusters is expected to be the most cost-efficient approach. Sharing, eventually across borders, CO2 transport, use and/or storage infrastructure will help with achieving economies of scale, and improving the business case. The complexity of CCUS

[40] REGULATION (EU) No 347/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on guidelines for trans-European energy infrastructure.

projects requires the inclusion of a great number of stakeholders, transparency, information and knowledge sharing, and forward looking, joint planning.

The project shall include the elaboration of detailed plans for the integration of CCUS in hubs and clusters linked to CO2 storage sites via hubs, pipeline networks and shipping routes, with due attention to national and border-crossing permitting and regulatory issues. Mapping and understanding the nature and longevity of emission sources, identification of transport corridors and modalities, and performing initial impact assessments, and developing local business models for delivery of CO2 capture, transport, utilisation and/or storage (including the separation of responsibilities across the CO2 value chain), within promising regions is important. Industrial clusters may include, for example, power generation, cement and steel factories, chemical plants, refineries, waste-to-energy plants, and hydrogen production facilities. In its initial phase, this topic could include the use of natural gas (for the production of low carbon hydrogen, in power plants and refineries). The assessment of cost-effective ('bankable') storage capacity in the selected regions is important. This can be sites for onshore or offshore storage capabilities. Interaction between CCUS hubs-and-clusters on the one hand, and renewables-based integrated energy systems, and/or circular production modes on the other; will need to be studied.

Close cooperation across the CCUS value chain, as well as engagement with local stakeholders, is paramount and so is knowledge exchange across CCUS projects. This includes identifying and involving relevant end users, public authorities and societal stakeholders and analysing their concerns and needs using appropriate techniques and methods from the social sciences and humanities. The exchange of knowledge and know how across CCUS projects needs to be continued and facilitated: therefore the successful project will be expected to continue the activities of the existing European CCUS project network[41].

C5-D3-CCUS-02-2022: Decarbonising industry with CCUS

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of up to EUR 29 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 - 8 by the end of the project – see General Annex D.

Expected Outcome: Successful, safe and economic demonstration of integrated-chain CCUS from relevant industrial sources will pave the way for subsequent first-of-a-kind industrial projects. The scale of the proposals should permit obtaining relevant data and experience required so that up-scaling to a first-of-a-kind plant can be envisaged as a next step.

[41] https://www.ccusnetwork.eu/

The impact of projects under this call will be determined by the extent to which the results will be extended to be used in further industrial facilities. In addition, it is important to demonstrate how the captured CO2 will be utilised and/or stored in a sustainable way. Projects carried out in areas with a sufficient concentration of CO2 emitting industries are considered prime sites for hub and cluster developments, and are expected to generate the highest impact on full-scale deployment of the results.

Scope: CCUS is one of the key promising technologies that can reduce CO2 emissions in the carbon intensive industry and the only pathway for very stringent GHG emission reductions from those industries that generate CO2 as part of their production processes. Relevant industrial sectors in which inclusion of CCUS could contribute to reaching climate neutrality are for example steel, iron and cement making, oil refining, gas processing, hydrogen production, sustainable biofuel production and waste-to-energy plants. However, CCUS in industrial applications faces significant challenges due to its high cost and the fierce international competition in the sectors concerned. These sectors currently account for up to 20% of global CO2 emissions.

The focus of this topic lies in demonstrating the integrated chain of mature CO2 capture technologies in industrial facilities with the perspective of geological storage and/or use. Based on a high TRL (7 – 8) CO2 capture project a detailed plan on how to use the results, i.e. the subsequent transport, utilisation and/or underground storage of the captured CO2 should be developed. Important aspects to address are of technical (e.g. the optimised integration of capture plant with industrial processes; flexibility, scalability; CO2 purity), safety (e.g. during transportation and storage), financial (e.g. cost of capture; cost of integration) and strategic nature (e.g. business models; operation and logistics of industrial clusters and networks). The project shall identify a detailed set of operational, environmental, technical and economic Key Performance Indicators (KPIs) to allow monitoring and assessing the progress achieved by the project.

The Commission considers that proposals requesting a contribution from the EU of up to EUR 29 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

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. Successful projects will be encouraged to join the EU CCUS knowledge sharing project network.

C5-D3-CCUS-03-2021: Cost reduction of CO2 capture (new or improved technologies)

Conditions related to this topic	
Expected EU contribution per	The EU estimates that an EU contribution of between EUR 10 and 15 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a

project	proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 6 by the end of the project – see General Annex D.

Expected Outcome: Significant step-change advances in CO2 capture rates, reductions in energy penalty and cost of CO2 capture as well as facilitating safe and economic integration into industrial clusters - which will in a short timeframe allow the uptake of CCUS in the power sector and energy intensive industries.

Scope: The high cost of carbon capture is still the most relevant stumbling block for a wider application of CCUS. Commercial deployment of CCUS requires a significant reduction of the energy intensity of the CO2 capture process for power plants or other energy-intensive industries, and a substantial decrease of the cost of capture. A continuous effort is needed to develop and demonstrate new or improved capture technologies.

The objective is the pilot demonstration of advanced CO2 capture technologies that have a high potential for increasing capture rates and efficiency, while reducing energy penalty and improving cost-efficiency of the whole capture process. Projects will test operating conditions and operational flexibility, and provide proof of the reliability and cost-effectiveness of these concepts, whilst at the same time evaluating the cost, technical requirements and operational and safety impacts on the industrial facility and the associated transport and storage infrastructure. The proposal should state credible and clearly defined targets and key performance indicators (KPIs) for the energy penalty reduction, the capture rate and the relative capital and operating costs of the capture process. Environmentally benign technologies have to be pursued and their environmental impact addressed in the project also in view of future scaling up.

Proposals are expected to bring technologies to TRL 6. Technology development should be balanced by an assessment of the societal readiness towards the proposed innovations, including by identifying and involving relevant end users and societal stakeholders (such as civil society organisations, non-governmental organisations, and local associations) in deliberative processes and analysing their concerns and needs using appropriate techniques and methods from the social sciences and humanities. Proposals shall include aspects of circularity and best use of resources.

Cross-cutting issues

C5-D3-CC-01-2021: Clean Energy Transition

Expected impacts

The European Green Deal aims to transform Europe into a fair and prosperous society with a modern, resource-efficient and competitive economy, with no net emissions of greenhouse gases in 2050. To decarbonise Europe, renewables must become the main energy source, while keeping the stability and resilience of the European energy system. Research and Innovation is needed to be able to achieve the Clean Energy Transition, while realizing also the ambitions of other EU policies like the New Circular Economy Strategy and the new Biodiversity Strategy and delivering on the objectives of the European Green Deal. It will also contribute to the Sustainable Development Goals of the United Nations (in particular SDG 7 Affordable and Clean Energy and SDG 9 Industry, Innovation and Infrastructure). At national level, policies and measures in clean energy research and innovation will support the achievement of the energy and climate targets, as outlined in the National Energy and Climate Plans.

The Clean Energy Transition Partnership (CETP) aims to empower the energy transition and contribute from a R&I perspective to the EU's goal of becoming the first climate-neutral continent by 2050. To achieve this ambitious goal, Europe needs to embark into a transformative process of both the energy system and its supporting technologies, as well as of the society. Key enabling and disruptive technologies, as well system innovation are essential for this transition. With robust investment in innovation and technology development, the energy transition turns into an opportunity for sustainable growth and competitiveness, creating high-quality jobs and leaving nobody behind.

It is expected that the partnership programme will:

a) Increase the directionality of clean energy transition research and innovation in Europe in line with the SET-Plan by a shared pan-European vision regarding the goal and direction of the required system transformation processes adapted to regional needs and availability of renewable energy resources

b) enable evidence based energy and climate policy formulation

c) Enable a wider systemic transition and energy supply required for the climate transition in all sectors of society; enabling the transition of the built environment, transport, industry and other sectors to clean, low carbon energy;

d) develop an innovation ecosystem for Europe's transition to clean energy and contribute to a resource-efficient energy system, both from an ecological and economic standpoint;

e) Be a building block to a zero-emission energy system for the decarbonisation of transport, buildings, industry, agriculture in the specific European environment;

f) Increase the engagement of consumers and prosumers (with for example awareness-raising campaigns and environmental respectful energy education) and in appropriate demand-response mechanisms and its integration in the energy system;

g) And finally, contribute to an energy system that meets the needs of different parts of society, in different geographical locations (urban and rural) and different groups;

Scope:

The Clean Energy Transition partnership is expected to contribute to these overarching goals by pooling national and regional resources/funding programmes thus overcoming a fragmented approach to the energy transition in Europe. In its Strategic Research and Innovation Agenda, the Clean Energy Transition Partnership will address the following areas: Development of clean and affordable energy production and conversion technologies; Development of a climate neutral, flexible and robust energy system; Storage and its integration in the energy system; Resource and energy efficiency and circular flows in the energy sector for an ecologically sustainable energy system; A just and inclusive energy transition; Sector integration and coupling; and Digital transformation.

The partnerships actions shall contribute to:

- a better cost performance by improving efficiency, sustainability, reliability and circularity of a broad portfolio of clean energy technologies and solutions;

- the integration of a wide range of new energy solutions and ‘first of a kind’ technologies on all levels of the energy system to give flexibility, promote and efficiently manage self-generation and consumption profiles and new holistic solutions for energy storage (surplus energy, peak load supply, inter-seasonal storage);
- the acceleration of the sustainable energy transition and societal development by the use of opportunities arising from the digital transformation and from data and information from the Copernicus programme, as well as the European Union’s Earth Observation programme.

The CETP will have to overcome the transnational challenges in the clean energy transition following the ambition of the European Green Deal via a joint, shared, transnational approach, engaging a wide variety of stakeholders including industry and research institutes.

The partnership has to provide a platform that makes research results available for the best use and implementation for all stakeholders and supports capacity building in areas requiring specific resources and expertise. By doing this, public and private investments in clean energy technologies development and deployment can be leveraged and capitalised to ensure adequate exploitation of results across Europe as needed.

Based on priorities identified in the Clean Energy Transition Strategic Research and Innovation Agenda, proposals should pool together the necessary financial resources from the participating national (or regional) research programmes with a view to implementing annual joint calls for proposals resulting in grants to third parties with EU co-funding. National efforts should reflect the ambitions outlined in the National Energy and Climate Plans, including on Member States participation in the SET Plan work streams. Participation of legal entities from international partner countries and/or regions including those not automatically eligible for funding in accordance with General Annex A is encouraged in the joint calls.

The Co-fund action shall 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 foresee a dedicated work package and/or task, and earmark the appropriate resources accordingly. The partnership shall also present and implement a joint programme of activities focussed on communication (participation in joint meetings and communication events), dissemination and exploitation.

The partnership is expected to collaborate closely with the following European Partnerships:

- Clean Hydrogen, Built Environment and construction, European industrial battery value Chain and Driving Urban Transition within the Cluster Climate, Energy and mobility
- Smart Networks and services, Clean Steel –Low carbon steelmaking, Carbon Neutral and Circular Industry and Geological Services for Europe within the Cluster Digital, Industry and Space
- Circular Bio-based Europe within the cluster Food, Bioeconomy, Natural Resources, Agriculture and Environment.
- And the Climate-KIC and InnoEnergy EITs

in order to ensure coherence and complementarity of activities. Proposers are expected to describe in their proposal the methodology for their collaboration and the aims they want to achieve with this kind of collaboration.

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. It is expected that the partnership will organise joint calls on an annual base from 2022-2027 and will consider ample time for the implementation of the co-funded projects.

The Commission considers that proposals requesting a contribution from the EU of around EUR *[245 million]* would allow these challenges to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts. Up to one proposal will be funded. The EU contribution for this action will be implemented in annual instalments of around EUR *[35 million]*.

Call conditions related to this topic are provided at the end of this call and in the General Annexes (here we will explain the general aspects, core of mandated organisations from MS, standards for call implementation, based on annual work programmes, flexibility to extend the scope of partners over time etc.)

Type of action: Programme Co-fund action

C5-D3-CC-02-2021: Support to the activities of the European Geological Services

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 20 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

Expected Outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

- An improved evidence-based decision-making and long-term sustainable management of Europe's subsurface, including offshore, needed to build a climate neutral continent.
- Comprehensive inventory of harmonised data on primary raw materials in the EU, with a focus on applications of critical raw materials[42] for energy storage and power generation, resulting in a higher level of independence for the EU.
- Comprehensive inventory of information on geothermal energy resources and subsurface storage capacities for sustainable energy carriers (hydrogen, heat and cold) and sequestration of CO_2, based on common and national scale assessment criteria and standardised reporting.
- Improved appraisal, protection and sustainable use – including appraisal of capacities for temporary storage - of Europe's groundwater resources, which are under increasing pressure because of climate change and competing uses of the subsurface.

[42] COM(2020) 474 - Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability

Improved adaptation of coastal zones to the effects of climate change and sea level rise.

- A strong and sustainable network of national Geological Survey organisations in order to provide geological knowledge and services on a Pan-European level

Scope: The growing demand for energy, raw materials and water is a key challenge for Europe, requiring a more integrated, efficient and sustainable use of these resources. Europe is increasingly dependent on global supply of mineral resources, in particular on those needed for application in power generation, energy storage and transport, for the transition to climate neutrality. However, until now there is no complete and harmonised data at the EU level on mineral resources and reserves. There is a need for standardised reporting and uniform appraisal of subsurface capacities for CO2 sequestration and temporary storage of sustainable energy carriers (including hydrogen and heat/cold) in order to support a secure, affordable and low-carbon energy supply. Groundwater resources are under increasing pressure as a result of climate change, as well as competing subsurface uses, including for mineral and energy resources. An up-to-date body of knowledge with high quality, policy-relevant geoscientific information and expertise, aggregated at the EU-level, at the service of European citizens, enterprises and institutions. This topic calls for concerted action to structurally address this challenge at EU level, which shall ultimately lead to a Geological Service for Europe as a point of entry into a permanent collaborative network of National Geological Survey organiusations.

For achieving these objectives, the action is expected to address a.o. the following issues:

- Re-evaluation of EU resources in primary raw materials and mining waste, with a focus on critical raw materials needed for climate transition, filling the currently existing gaps in data and information at EU level.
- Developing a database with FAIR[43] and harmonised data on mineral resources and reserves (excluding fossil fuels) according to United Nations Framework Classification for Resources (UNFC)[44], integrated in or linked to the EC managed geoportals (EU Open data portal[45] and EU INSPIRE Geoportal.
- Developing an EU International Centre of Excellence on Sustainable Resource Management focused on promoting and building capacity on United Nations Framework Classification for Resources (UNFC) for mineral resources (primary and secondary) and supporting the United Nations Resource Management System (UNRMS) in line with the UN 2030 Agenda for Sustainable Development.
- Building and maintaining an integrated European geothermal resources database based on uniform appraisal techniques and resource classification standards. Extend the geothermal database with assessed storage options for heat and cold.

[43] FAIR (Findable, Accessible, Interoperable, Reusable)
[44] https://www.unece.org/energywelcome/areas-of-work/unfc-and-resource-management/about-unfc-and-sustainable-resource-management.html
[45] https://data.europa.eu/euodp/en/home

- Deploying and maintaining a European storage atlas for CO2 and sustainable energy carriers like hydrogen and compressed air. Develop the knowledge for the subsurface management and planning of storage sites for CO2 and sustainable energy carriers.
- Transnational, harmonised data gathering, managing under the FAIR[46] principles, monitoring and evaluation of groundwater dynamics and groundwater quality.
- Collating and integrating geological and climate related information and data to assess and map coastal vulnerability, and to optimise siting of offshore windfarms (as well as associated infrastructure), in support of multifunctional use of pan-European marine space.
- Developing - and partly implementing strategic within the CSA - a research agenda, which includes the piloting of innovative cross-country data generation methods, to help achieve the expected impacts. Coordinating, integrating and aligning R&I programmes of European geological surveys.
- Developing a user-friendly digital Europe geological information system providing permanent data access, based on FAIR, and disseminating accurate, up-to-date, relevant and impartial data, information and knowledge developed by the partnership.
- Transformation of these data into decision support information and intelligence, including the use of innovative modelling and visualisation in multiscale digital products.
- Dissemination and communication of information and knowledge to stakeholders, including the general public.
- Create a strong network of geological surveys, and develop a permanent structure in the form of a Geological Service for Europe able to sustain this network and the geological information system after the end of the programme.

The use of own resources, for example for implementing the proposed research agenda, will increase the potential impact of the action, and is strongly encouraged.

C5-D3-CC-03-2021: Support to the activities of the ETIPs and technology areas of the SET-Plan

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of maximum EUR 1 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Award criteria	Only up to one project will be funded in the sector of • carbon capture storage and use • geothermal systems

[46] FAIR (Findable, Accessible, Interoperable, Reusable)

	• hydropower • ocean energy • photovoltaics • renewable fuels & bioenergy • concentrated solar thermal energy (CSP & STE) • renewable heating and cooling • wind energy • energy efficiency in industry
Type of action	Coordination and Support Action

Expected Outcomes: Project results are expected to contribute to the following outcomes:

- Consolidation of strong and sustainable networks in the different technology areas covered through the Strategic Energy Technology (SET) Plan and its integrated roadmap.
- Cooperation among ETIPs and similar stakeholders fora, support to existing SET Plan Implementation Plans and advancement towards more interconnected activities, both in terms of contents and implementation mechanisms.

Scope:

The European Technology and Innovation Platforms (ETIPs) and similar stakeholders fora support the development and implementation of the SET Plan R&I priorities by bringing together relevant stakeholders from industry and research in key areas. They develop research and innovation agendas and roadmaps, industrial strategies, analysis of market opportunities and funding needs, understanding of innovation barriers and exploitation of research results, which are in line with the Recovery Plan for Europe and latest EU climate and energy related policies. They also provide consensus-based strategic advice to the SET Plan initiative covering technical and non-technological aspects.

In 2015, the launch of the Energy Union saw the SET Plan incorporated as the Energy Union's fifth pillar on 'Research, Innovation and Competitiveness'. Through the Communication "Towards an Integrated Strategic Energy Technology (SET) Plan", the Integrated SET Plan set ambitious R&I targets which remain relevant and essential in the new context of the European Green Deal and the Recovery Plan for Europe.

Considering the overarching aim of the clean energy transition, ETIPs and/or similar fora are encouraged to align and coordinate their activities, defining cross-cutting aspects for accelerating the clean energy transition and contribute to the development of a European Research Area in the field of Energy. Proposals should take into consideration the specific needs of the sector they address and the emerging policy priorities for their implementation as well as the coordination with other initiatives/projects, in order to avoid overlaps.

ETIPs should ensure the participation of companies (industry and SMEs), research organisations and NGOs from a representative number of SET Plan countries, with a balanced representation and establishing links with national authorities. To maximise their impact, they should develop and implement robust outreach approaches to span the whole of EU and societal engagement actions.

Special attention should be given to issues related to the challenges needed to reach the goals of the European Green Deal, including, but not limited to, technological pushback, industrial production, societal transformation, and just transition. Likewise, contributions to the goals of the European Research ERA in the field of Energy, in particular regarding how to incentivise investing in research and innovation should be addressed.

Furthermore, proposals should develop a dissemination and exploitation strategy, while aligning dissemination activities with other existing ETIPs (e.g. joint workshops, thematic conferences, webinar series, regular exchanges, etc.). All outputs of these CSAs will feed into the SET Plan information system (SETIS).

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 should address one of the following sectors[47]: carbon capture storage and use, geothermal systems, hydropower, ocean energy, photovoltaics, renewable fuels & bioenergy, concentrated solar thermal energy (CSP & STE), renewable heating and cooling, wind energy, energy efficiency in industry.

Proposals submitted under this topic are encouraged to include actions designed to facilitate cooperation, across Europe, with other projects and to ensure the accessibility and reusability of data produced in the course of the project. Proposals should include a finance and sustainability plan for future continuation beyond the lifetime of the proposal. (Indicative project duration: 3 years).

[47] For information, batteries are addressed in Destination 2. Solar fuels are addressed in Cluster 4, topic RESILIENCE-28-2021(‘Creation of an innovation community for solar fuels and chemicals’).

Destination 4 – 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.

Demand side solutions and improved energy efficiency are among the most cost effective ways to support the transition to climate neutrality, reduce pollution and raw materials use, to create inclusive growth and employment in Europe, to bring down costs for consumers, to reduce our import dependency and redirect investments towards smart and sustainable infrastructure. The transition to a decentralised and climate neutral energy system will greatly benefit from the use of digital technologies which will enable **buildings** and **industrial facilities** to become inter-active elements in the energy system by optimising energy consumption, distributed generation and storage and vis-à-vis the energy system. They will also trigger new business opportunities and revenue streams for up-graded, innovative energy services which valorise energy savings and flexible consumption.

Buildings are responsible for 40% of energy consumption in the EU and are pivotal to the energy transition in all aspects: energy efficiency; penetration of renewables; smart grid management. From an energy transition perspective, the key R&I breakthroughs are: cost-effective renovation for energy-efficient, renewable-intensive and smart grid-friendly buildings; digitalisation of building energy; optimisation of energy usages in buildings.

Beyond the energy challenge, the built environment is responsible for a significant share of our consumption of resources: 50% of all extracted materials and 30% of water consumption. At the same time, the embodied carbon in the built environment has been estimated to 10-12% of total carbon emissions in several member states. Construction and deconstruction/demolition waste are one of the heaviest and most voluminous (25%-30%) waste streams generated in the EU.

In line with the new European Bauhaus aiming to "bring the European Green Deal to life in an attractive, and innovative and human-centered way", the sustainable built environment should go beyond merely improving the energy and resource efficiency of buildings and also include a qualitative, aesthetic and human dimension. At the intersection of science, technology and the arts, new creative design and architectural solutions should be developed to ensure the sustainable renovation of the existing EU building stock for the well-being of its users. In particular the renovation or adaptive reuse of historical and heritage buildings and sites needs to embrace quality principles to preserve the cultural values of Europe's historical environment and local architectural indentity.

Expected impacts at Destination-level and their link to expected impacts of the Strategic Plan

Activities under this Destination should set out a credible pathway for contributing to the following **Destination-level expected impacts** (more detailed impacts for each thematic area are elaborated in the introductory text of the thematic area):

a) Based on inclusive and people-centric R&I, delivering the technology and socio-economic breakthroughs necessary to **achieve climate neutrality and the transition to zero pollution of the building stock by 2050**.

b) Increased energy efficiency and reduced Greenhouse Gas (GHG-) and air pollutant emissions through recovery, upgrade and/or conversion of industrial excess (waste) heat, as well as electrification of heat generation in industry.

These Destination-level impacts will directly support the **Strategic Plan's expected impact** of *"Efficient and sustainable use of energy, accessible for all is ensured through a clean energy system and a just transition"*.

Highly energy-efficient and climate neutral EU building stock

The heading "Highly energy-efficient and climate neutral EU building stock" will focus on both, the energy challenge in buildings and, more broadly, the transformation of the built environment towards more sustainable living. The former challenge will be addressed through very specific and focused R&I actions (BEE topics) implemented through standalone calls for proposals as part of this cluster. The BEE topics will seek to achieve the following impacts:

- More energy efficient building stocks supported by an accurate understanding of buildings performance in Europe and of related evolutions (topics BEE-01, BEE-02 and BEE-03).
- Building stocks that effectively combine energy efficiency, renewable energy sources and digital and smart technologies to support energy system decarbonisation (topics BEE-04, BEE-05 and BEE-06).

Addressing the broader transformation of the built environment, though, will require a larger involvement of all players across the built environment value chain and throughout building life cycle. To this end, a co-programmed partnership has been proposed on a people-centric, sustainable built environment (Built4People- B4P topics) to develop holistic R&I for an effective transition to sustainability. All the R&I actions funded from Horizon Europe, which address the challenges related to the buildings and construction sector, will contribute to the achievements of the Built4People Partnership goals and will benefit from the coordinated approach within the community of its partners and stakeholders. However the actions implemented directly under the partnership (B4P topics) will be cross-cutting in scope and larger in size than the standalone calls on buildings energy and will rely on a strong cooperation between a broad range of players. The B4P topics will seek to achieve the following impacts:

- Increased rates of holistic renovations that result in higher performance with lower environmental impacts (topics B4P-07, B4P-08 and B4P-09).
- Higher quality, more affordable built environment preserving climate, environment and cultural heritage and ensuring better living conditions (topics B4P-10, B4P-11, B4P-12 and B4P-13).

Building Energy Efficiency: Enhancing energy performance of the building stock

C5-D4-BEE-01-2021: Advanced energy performance assessment and certification[48] [49]

Conditions related to this topic	
Expected EU	The EU estimates that an EU contribution of between EUR 3 and 5

[48] Please note that BEE and B4P topic numbering has evolved compared to the prevision version of the draft work programme, due to some restructuring of the topics on buildings in Destination 4. Also, the title of some topics has been updated to better reflect the intended scope and avoid any misunderstanding. For each topic, a footnote clarifies the former reference and (if applicable) topic name.

[49] This topic is the revised version of C5-D4-BEE-02-2021: Advanced energy performance assessment and certification.

contribution per project	million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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 outcomes: Project results are expected to contribute to all of the following expected outcomes:

- Improved construction quality and service life compliance;
- Improved accuracy of energy performance assessment and any other assessment conducted in parallel, reduced gap between assessment and actual performance;
- Improved and automated monitoring of energy performance of buildings, and other relevant life-cycle performance aspects with a direct link to the energy efficiency performance;
- Improved user-friendliness of Energy Performance Certificates and post-occupancy performance data, in terms of clarity, accuracy, trade-offs and usability of the information provided;
- Contribute to the development of design standards and practices based on actual performance;
- More reliable understanding of energy and environmental performance in the early stage of the building life cycle, and over service life, based on robust and consistent assessment practices across the buildings sector and across Member States and Associated Countries;

Scope:

The next generation of energy performance assessment and certification schemes needs to support the transition towards a climate neutral building stock over the full life cycle, relying on technological innovations to improve speed and quality of as-built performance assessment and service life compliance checks, also linking to other instruments such as building logbooks, building renovation roadmaps, Level(s) and other datasets. Energy performance assessment and certification schemes should seek to work coherently, where relevant, with other performance data generated over the building's life cycle. This can include well-being, indoor air quality, noise and acoustic quality, daylight levels, pollutants and health related data, as well as data pertaining to other issues such as accessibility of buildings, and consumption of non-energy resources such as water.

The proposal should:

- Develop more reliable, cost-effective and highly replicable energy performance calculation methods also addressing, in parallel, relevant life-cycle performance aspects (e.g. well-being, indoor air quality, acoustics, water consumption, or whole life carbon) with a direct link to the energy efficiency performance
- Address the definition and demonstration of advanced and innovative approaches for building energy performance and certification, and how these can interact with other relevant life cycle performance data and certification, focusing on a credible

assessment of building intrinsic performance but also increasingly working towards output-based assessments using available building data;

- Seek to incorporate in those approaches social and economic indicators;
- Develop dynamic energy and other relevant life-cycle performance assessment and certification databases as a unique source of information on individual buildings over their lifetime for home owners, investors, real estate agents and public authorities;
- Demonstrate how data from smart sensors can be included in assessments in a dynamic way, also exploring, where relevant, how to combine building asset rating with building operational rating, and how to use digital innovations for the assessment of energy and other relevant life-cycle performance;
- Ensure the proposed solutions build on the results of previous projects dealing with building performance including Energy Performance Certificates (EPCs), also considering where relevant integrating building renovation passports or roadmaps in EPCs;
- Ensure the proposed solutions allow for synergies with other relevant instruments (e.g. the smart readiness indicator under Directive 2010/31/EU, building renovation passports and relevant parts of Level(s));
- Ensure that the proposed solutions comply with, and support a broad adoption of, relevant EU standards and codes in order to allow for an EU-wide deployment;
- Ensure the involvement of relevant stakeholders (including European, national and regional certification bodies and consumer organisations);
- Clustering and cooperation with other relevant projects is strongly encouraged; in particular, liaison and synergies with the Horizon Europe Partnership on ‘People-centric sustainable built environment’.
- Proposals submitted under this topic should include a clear business case and exploitation strategy, as well as demonstration activities (at least three demonstration use cases) of an adequate scale.
- 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.

C5-D4-BEE-02-2021: Industrialisation of deep renovation workflows for energy-efficient buildings[50]

Conditions related to this topic

[50] This topic is the revised version of C5-D4-BEE-04-2021: Industrialisation of deep energy renovation workflows. It also includes parts of C5-D4-BEE-01-2021: Automated and robotic construction for energy efficient buildings and C5-D4-BEE-03-2021: Whole life cycle NZEB digital twins, both of which have been deleted.

Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 5 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 8 by the end of the project – see General Annex D.

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

- Significant improvement in productivity of construction and renovation processes for energy-efficient buildings, supporting an increase in scale in the renovation process and streamlining resource efficient nearly zero-energy performance renovation: 30 % waste reduction; improved quality of renovation; 40 % time spent on site and 25% costs reduction;
- More affordable renovation projects for owners, for all building types but with a specific focus on residential buildings;
- Enhanced quality of construction, backed up by post-occupancy evaluations, also supporting a better integration of design and construction activities, streamlining commissioning of buildings, in particular in relation to energy management but also taking into account cross-cutting issues such as accessibility of buildings;
- Reduced performance gap between as-built and as-designed (difference between theoretical and measured performance), allowing tracking performance across the life cycle;
- Increased trust towards construction and renovation processes, by allowing tracking energy performance across the life-cycle;
- Upskilled workforce for industrialised renovation workflows, including automated and robotised construction / renovation, relying on interoperable digital modelling data;
- Enhanced safety of the construction workforce and increased acceptance of robotic support for deep renovation;
- Innovative, tailored business models for deep renovation allowing increased scale of renovation, generating economies of scale and increasing the potential for attractive and affordable packages for end users including financing;
- Tailored access to building information across the life cycle for relevant stakeholders (owners, facility managers, contractors, public authorities);
- Integration with distributed renewable energy sources in neighbourhoods and districts, favouring the emergence of related initiatives (e.g. renewable energy communities);
- Enhanced synergies of renovation with local resources, e.g. district heating & cooling networks;

Scope:

Several recent projects & calls have focused on prefabrication for deep renovation, but more work is needed to innovate seamless workflows from design through to offsite manufacture, installation, and compliance checking on site, also ensuring due consideration of life cycle performance. There is also a need for more demonstrations across the EU.

Proposals should:

- Investigate innovative approaches for industrialised deep renovation, covering the whole workflow from design through to offsite manufacture, installation, compliance checking on site and end strategies for maintenance, operation and end of life;
- 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);
- Develop significantly improved integrated digital twin solutions that can support all stakeholders involved in the different phases of the construction or renovation processes, i.e. from concept to end-of-use, including design, construction, commissioning, operation (management and maintenance) and, where relevant, change of 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.);
- Investigate the use of robotic systems and automation such as additive manufacturing, on-site automated and robotic systems (e.g. robots for building component assembly), drones and autonomous vehicles (e.g. for surveying, inspection and monitoring), and other types of automated support to augment workers' capability and safety (e.g. lift robots, exoskeletons) for deep renovation;
- Investigate the application of the proposed approaches at neighbourhood- and district-level, with the aim to maximise synergies in renovation work and processes, decrease costs, and to optimise the use of energy-related shared district resources (e.g. heating and cooling networks, renewable energy sources, energy storage facilities, etc.);
- Select processes and technologies that have a maximum potential for rapid and broad deployment at EU level, with due consideration of the sector's practices;
- Ensure effective involvement of the buildings supply chain, in particular SMEs, as well as of building owners/tenants and other relevant stakeholders;
- Where relevant, investigate whether and how the proposed approaches could apply to cultural heritage buildings;
- Clustering and cooperation with other relevant projects is strongly encouraged; in particular, liaison and synergies with the Horizon Europe Partnerships on 'People-centric sustainable built environment' and 'Driving Urban Transitions'.
- Ensure the proposed approaches allow to reach the highest level of energy performance, also considering other relevant aspects (e.g. life cycle, accessibility), while keeping costs in an attractive range for owners;
- Demonstrate, based on well-defined metrics and key performance indicators, that the innovative approaches proposed lead to fewer mistakes, less waste, higher resource efficiency, higher quality in particular with regard to energy performance (reduced performance gap), increased replicability across sites, and other relevant life cycle

aspects, enhanced safety of workers and their ability to work alongside robots, and faster construction;

- Investigate business models in view of mass deployment and EU-wide impact, seeking to address split of incentives between the owner and tenant of a building as a barrier to investments;
- Lead at least 3 large-scale demonstration to assess the proposed approaches for a variety of buildings typologies representative of the EU building stock, ensuring the most adequate coverage of climatic conditions.

C5-D4-BEE-03-2021: Advanced data-driven monitoring of building stock energy performance[51]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 8 by the end of the project – see General Annex D.

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

- More robust, improved and consistent monitoring of performance (energy and other relevant aspects, such as indoor environment quality and life cycle) of buildings across the EU sectors and through the whole value chain;
- Better informed planning of building infrastructure (e.g. renovation roadmaps, heating & cooling systems, district heating networks, strategies for whole life carbon reduction etc.) and better informed investment decision-making for designing future buildings and building processes;
- Successfully tested smart energy services on the basis of advanced, high-quality building stock performance data;
- Significant and measurable increase in the use of open, real-time and reliable building data from multiple sources;
- Development of accurate methods that facilitate collection of data from the building stock (e.g. to support policy making and policy impact assessment or to substantiate performance guarantee schemes and contribute to de-risking investments in a climate neutral building stock over the full life cycle);

[51] This topic is a revised version of C5-D4-BEE-08-2022: Advanced use of energy performance data from buildings. It has been moved to 2021 to ensure the best balance between 2021 and 2022 BEE calls.

- Better availability of big data and big data analysis facilities for real-life scale research, simulation and policy-making;
- Make available open access and standardised European buildings data repositories, also supporting the development of related EU initiatives (e.g. the EU Building Stock Observatory, JRC E3P ,roadmap for whole life cycle carbon emissions reduction);
- Support the effective implementation of EU policies that drive the transition to a green, digital and sustainable economy, and contribute to enhance the quality of the building stock across the board (e.g. quality of life and working, inclusiveness and accessibility, etc.);

Scope:

The proposal should:

- Enhance the collection and quality of energy and related (e.g. life cycle) data for buildings (including heating, ventilation and air-conditioning, all technical equipment, lighting and other appliances) through various sources such as manufacturers' data, BIM and digital twin models, surveys, digital logbooks, sensors, meters, interfaces (statistical, structured and big data) and Level(s);
- Explore approaches to integrate dynamic data from buildings (e.g. coming from sensors) with metering static data (e.g. data spaces, energy performance certificates databases) and statistical data;
- Ensure the proposed approaches build on interoperability solutions that and allow for seamless collection and use of data from the buildings, systems and subsystems;
- Develop new or enhance existing open source data analytics dashboards and prediction tools;
- Develop improved tools for digital simulation and digital twinning;
- Develop, enhance and integrate existing open data sharing platforms, including where relevant by refining and integrating building data reference architectures and making links with relevant data spaces;
- Promote fair data management practices to ensure findability, accessibility, interoperability and re-usability of data;
- Clustering and cooperation with other relevant projects is strongly encouraged; in particular, liaison and synergies with the Horizon Europe Partnerships on 'People-centric sustainable built environment' and 'Driving Urban Transitions';
- Demonstrate digital data exchange platforms for building;
- Demonstrate real use cases valorising high quality building performance data, e.g. to accurately monitor energy consumption and production across different fuels (for instance integrated heating and cooling and hybrid systems) as well as other relevant performance criteria;
- Demonstrate that the proposed solutions allow to significantly improve the monitoring of the building stock performance, taking into consideration all relevant aspects (e.g. environmental, economic, and social ones);

The solutions have to be interoperable and able to interact with grid management platforms.

Building Energy Efficiency: Future-proofing the building stock for smartness and high energy efficiency

C5-D4-BEE-04-2022 Demand response in energy-efficient residential buildings[52]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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 Outcomes: Project results are expected to contribute to all of the following expected outcomes:

- Increased potential benefits, trust and acceptability of demand-response solutions for residential consumers;
- Advanced asset control and aggregation approaches that enable the participation of residential buildings in commercial demand response;
- Secure a pool of assets relevant for demand response in the residential sector;

Scope: Address the large but untapped potential of the residential sector for Demand Response with a view to support the energy transition at system level while respecting user privacy, comfort and ownership.

Proposals should:

- Investigate innovative demand response solutions for the residential sector, including new control modes and asset optimisation techniques involving as many devices as possible;
- Ensure that the proposed solutions comply with the principle of privacy by design and with best practices on data protection;
- Ensure that the proposed solutions allow to minimise the effort required to elicit user preferences, also investigating innovative approaches for user segmentation and engagement;
- Take due account the regulatory frameworks of the regions / countries in which the proposed solutions could be deployed in designing their innovation, and shaping related exploitation activities;
- Seek to the best consideration of social and economic enablers in the design of the innovative solutions;

[52] This topic is a revised version of C5-D4-BEE-06-2022 Demand response in energy-efficient residential buildings.

- Clustering and cooperation with other relevant projects is strongly encouraged; in particular, liaison and synergies with the Horizon Europe Partnership on ‘People-centric sustainable built environment’;
- Demonstrate that the proposed solutions lead to reducing costs of small demand response assets e.g. through improved models and faster data processing and, are scalable and replicable;
- Demonstrate that the proposed solutions are suitable for explicit demand response, or a combination of both explicit and implicit residential demand response;
- Each project shall include at least three demonstration sites located in different climatic regions.

C5-D4-BEE-05-2022: Renewable-intensive, energy positive homes[53]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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.

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

- Deliver the next generation of new constructions and renovation of cost-effective energy positive, climate neutral residential buildings;
- Streamline the integration of advanced smart technologies, renewable energy and storage solutions in residential construction and renovation projects;
- Deliver buildings and technical elements that are capable to adapt to different user profiles and lifestyles, improving air quality, human health and well-being parameters;
- Develop the necessary skills and competences among the workforce.to support a rapid uptake of energy positive buildings in the residential sector.

<u>Scope</u>: the aim is to move beyond NZEB (nearly zero-energy buildings) for new constructions and to the extent possible, for renovations, and to streamline energy positive buildings, ensuring buildings can marry high energy performance with maximum flexibility and adaptability to a changing society in a cost-effective manner. This is a key challenge for the residential sector, where energy positive houses should become the norm.

Proposals should:

[53] This topic is a revised version of C5-D4-BEE-07-2022: Energy positive homes.

- Investigate and demonstrate approaches for the construction of new energy positive residential buildings (and /or the renovation of existing residential buildings), with a focus on multi-family, multi-storey buildings, encompassing all relevant areas:
  - design phase (aesthetic and technical solutions and their potential, passive and active strategies, sustainable design);
  - integrated design and construction concepts;
  - reconfigurable designs and technical elements capable of adapting to different user profiles and lifestyles;
  - selection of affordable and efficient construction materials, building on previous projects which have developed efficient insulation materials with improved properties and smart materials;
  - innovative processes from manufacturing to construction site;
  - integration of renewable energy production for heating and cooling, electricity production (e.g. BIPV and BAPV), and where relevant, thermal and electrical storage, including shared at neighbourhood and district levels; for existing buildings, cost-effective, innovative solutions that allow to (at least) fully cover the energy consumption of the building (electricity, heat and cooling) with renewable energy;
  - advanced use of smart management technologies (for control and operational issues, Building Management Systems (BMS) or Building Automation Systems (BAS)) to improve air quality, human health and well-being parameters, to facilitate engagement and inclusiveness of occupants and support measurement of (as-built) building performance;
  - reuse and recycling of elements, components and materials, in particular in relation to buildings end of life, also minimizing embodied carbon emissions over the whole life cycle, in particular for smart technologies;
  - where applicable, the use of grey- and black-waters.
- Ensure that the cost of such buildings/apartments does not increase substantially compared to current local / regional practises;
- Clustering and cooperation with other relevant projects is strongly encouraged; in particular, liaison and synergies with the Horizon Europe Partnership on 'People-centric sustainable built environment';
- Each project shall include at least three demonstration sites located in different climatic regions;
- The demonstrations will have to span a continuous interval of at least twelve months and to ensure measurement of (as-built) building performances. The relevant building professionals (e.g. architects, installers, workers, craftsmen, building managers) shall be involved;
- Projects shall assess the sustainability of the proposed solutions in environmental, social and economic terms, considering among others the embodied carbon emissions from materials. The reuse and recycling of elements, components and materials of the proposed solutions at the end of life should be ensured.

C5-D4-BEE-06-2022: Smarter buildings for better energy performance[54]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 8 by the end of the project – see General Annex D.

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

- Deliver innovative, affordable, user-friendly and accessible products and systems to continuously monitor and improve the energy performance of buildings;
- Increase energy performance through the optimisation and integration of different technologies, including renewable energy and storage, and services;
- Allow to use smart products and services to achieve savings where energy renovation is not an option;
- High replicability to increase number of buildings with smart building devices and digital infrastructure resulting in a higher smart readiness rating;

Scope:

Improvement and cost-reduction of technologies to predict, assess, monitor and control in real time the energy performance of buildings, including energy efficiency, renewables, storage and their optimisation.

The proposal should:

- Develop new or enhance existing solutions for interoperability of systems, including between building automation and control systems (BACS) and other technical building systems and devices, as well as between buildings and the grid;
- Investigate innovative approaches to ensure high level of security and privacy by design in buildings;
- Investigate approaches to reduce costs of systems allowing the integration of energy efficiency, renewables, storage and their optimisation;
- On the basis of the above, demonstrate the potential for energy savings from energy management solutions based on smart technical building systems (predictive controllers, smart thermostats, active sensors, smart lighting, etc.);

[54] This topic is a revised version of C5-D4-BEE-10-2022: Smarter buildings for better energy performance

- Assess the contribution of proposed solutions to the enhancement of smart readiness of buildings as rated by the smart readiness indicator under Directive 2010/31/EU;
- Clustering and cooperation with other relevant projects is strongly encouraged; in particular, liaison and synergies with the Horizon Europe Partnership on ‘People-centric sustainable built environment’;
- Demonstrate that the developed solutions are user-friendly and ensure the desired indoor environment quality and user satisfaction;
- Where possible, demonstrate that such solutions can build flexibly on services/products not originally intended for energy management (e.g. a smart home system).
- Each project shall include at least three demonstration sites located in different climatic regions.

People-centric, cost-effective and sustainable renovation

The following topics are the cross-cutting actions implemented under the co-programmed European Partnership B4P:

C5-D4-B4P-07-2021: Demonstrating integrated technology solutions for buildings with performance guarantees[55]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 5 and 7.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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 outcomes: Project results are expected to contribute to all of the following expected outcomes:

- Demonstrated viability of, and proven integrated technology solutions for, performance guarantees and performance-based contracts to increase buildings energy performance but including aspects going beyond energy towards a broader range of climate- and environment- relevant matters (e.g. resource efficiency, whole life carbon, etc.);
- Enhanced consumer trust in guarantees of performance and related contracts;

[55] This topic was formerly C5-D4-B4P-11-2021.

- Increased number of market actors, especially SMEs, offering performance-based business models;
- Enhanced awareness of end users and capacity building of businesses on performance-based contracts.

Scope: The proposal should:

- Design and demonstrate innovative integrated technology solutions based on state-of-the-art components (envelope, heating, ventilation and air-conditioning, cooling, automation and control, renewable energy, etc.) solutions for cost-effective buildings' overall performance enhancement with performance guarantees;
- Investigate the viability of performance-based business models combining those technology solutions with attractive and innovative contractual frameworks for performance guarantees and testing them with the relevant market players (e.g. energy suppliers, product manufacturer, technology/service providers);
- Develop business models that suit new industrialised design and production methods, and include enhanced energy and resource (based on suitable Level(s) indicators) performance guarantees with longer commissioning and condition-based maintenance to replace maintenance contracts;
- Develop performance contracts that work with industrialised solutions for the renovations in the residential sector, valorising energy and environmental performance, resource and energy efficiency, energy flexibility (through demand response) and comfort (Comfort Performance Contracts) for all building elements (e.g. building envelope, equipment & systems, energy storage);
- Build, where possible, on existing business approaches that have shown effectiveness for renovation (e.g. one-stop-shops, ESCOs);
- Ensure that those business models make use of digital tools (e.g. energy management systems, block chain, digital logbooks) to increase data availability for measurement and verification and therefore increase the traceability of performance (e.g. energy savings, energy generation, GHG emissions, location of components and substances in the buildings) and to ease the implementation of performance-based contracts;

C5-D4-B4P-08-2021[56]: More sustainable buildings with reduced embodied energy / carbon, high life-cycle performance and reduced life-cycle costs

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 5 and 7.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action

[56] This topic was formerly C5-D4-B4P-12-2021.

Technology or societal readiness level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex D.

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

- Increased and more traceable reduction of the GHG emissions of buildings in design, construction, renovation, operation and end of life;
- Faster market uptake of design solutions, materials, products, techniques and business models that are demonstrated to reduce significantly building related life-cycle costs and impacts, including whole life emissions, compared to current building completions;
- Mainstreamed affordable high life-cycle performance, and improved circularity of buildings in construction and renovation

Scope: The proposal should:

- Demonstrate innovative design, construction and renovation methods, design and technology solutions to reduce energy consumption and carbon footprint of the built environment across the life cycle, from construction to end of life thanks to, inter alia, applying circularity principles throughout the design and construction process, flexible use and lifecycle extension by design, design for deconstruction, disassembly and reassembly, integration of waste, reused, recycled, upcycled and bio-based materials and components, optimisation of design, construction and operation by means of digital tools;
- Deliver scalable full building demonstrations (both new and renovation) with validated performance measurements based on appropriate Level(s) indicators, demonstrating that the proposed methods and technology solutions optimise the use of energy and resources, and minimise the emissions of CO_2 and other air pollutants across all phases of the life cycle, including construction and renovation works, and operation;
- Integrate the use of low embodied carbon products and solutions, including those that are locally sourced and bio-based with low carbon impact and capturing / storing CO_2, selected based on modelling of their performance in terms of (inter alia) insulating, cooling, acoustic and hygrometric performance, ageing patterns, potential for deconstruction and/or reuse at end of life, and potential for automated / mechanised deployment;
- Deploy innovative design and construction and renovation techniques that minimise the overall life-cycle environmental impact from the use of resources, materials and energy;
- Identify and integrate local sources of reused construction products and secondary raw materials for building renovation in urban and rural planning scenarios;
- Where relevant, investigate whether and how the proposed approaches could apply to cultural heritage buildings;
- Deploy advanced, market-ready prefabs and multifunctional materials and components with optimal recycling and re-using potential (e.g. through new designs enabling the

re-use) and optimal performance across relevant areas (energy, durability, safety and protection against fire);

- Demonstrate innovative solutions for optimal design, construction, operation and maintenance of sustainable buildings, including efficient technical building systems, automation and control, digital building logbooks, digital twins and other tools;
- Demonstrate the solutions in diverse geographical areas, with various local environmental, social, and economic conditions;
- Seek to support the integration of local sources of secondary raw materials and reused or recycled elements for building renovation;
- Clustering and cooperation with other relevant projects is strongly encouraged; e.g. with the Horizon Europe Partnership on 'Driving urban transitions'.

C5-D4-B4P-09-2021: Cost-effective, sustainable multi-functional and/or prefabricated holistic renovation packages, integrating RES and including re-used and recycled materials[57]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 9 and 11 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

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

- Increased scale and productivity in the renovation process: demonstrated and quantified decrease of on-site construction / renovation work time (at least 30% and towards 50%);
- Benchmarked and quantified improvement of insulation and air-tightness compared to standard renovation solutions;
- Demonstrated improvement of indoor environment and user comfort and satisfaction, as well as accessibility, increasing attractiveness of renovation for buildings owners and users;
- Improved affordability of sustainable renovation and RES systems in buildings, in particular for households experiencing energy poverty issues;

[57] This topic was formerly C5-D4-B4P-13-2021.

- Demonstrated reduction of embodied energy and CO_2 of renovation, and emission of air pollutants over the life cycle;
- Increased deployment of built-in renewable energy generation solutions for on-site multi-purpose (heating, cooling, electricity) renewable energy generation;
- Increased share of reused and /or recycled and/or biosourced construction materials / products used in building renovation to contribute to circular economy;
- Where relevant, broader application of urban mining;
- Faster uptake of EU-wide standards or certification of reused and / or recycled construction materials / products.

Scope: Proposals are expected to deliver large-scale, real life demonstration of promising technology innovations already demonstrated at lab level. Proposals should cover all of the following:

- Develop renovation solutions for a range of needs (from renovations limited in scope to deep renovations) applying predominantly re-used and / or recycled and/or biosourced construction materials / products in a cradle-to-cradle approach, allowing for installation without significantly modifying the structure of the building (or without overloading existing structures) and demonstrating a high replication and industrial potential;
- Develop multi-functional (passive & active) and scalable renovation solutions to improve energy performance of buildings, applicable to different building types based on prefabricated components and integrated RES systems;
- Develop building envelope solutions with integral means for combined active/passive management of energy transfer, i.e., integrating RES for active heat and sound insulation and direct on-site renewable electricity generation;
- Seek to support the integration of local sources of reused components and secondary raw materials in the renovation packages;
- Develop novel testing methodologies oriented towards assessing the long-term performance of the elements. This should include the estimation of durability and service life;
- Model and test in actual scale the materials and components selected;
- Benchmark energy and environmental performance (applying the appropriate Level(s) indicators), monitoring (at least one year) at real scale of new solutions in parallel with current situation in order to demonstrate that the well-engineered systems satisfy project and regulatory-compliance requirements; demonstrate cost-effectiveness of the renovation solutions over the lifetime;
- Assess the risks related to major disruptive events (such as flooding, heat waves, and/or other climate-driven events and/or earthquakes) that apply to the geographical zones targeted and, where relevant, include an analysis of resilience of the renovated building / infrastructure against those major disruptive events;
- Demonstrate, based on clear and thorough documentation of relevant activities, that the proposed solutions lead to reduced maintenance costs, lead to an improvement of indoor environment and user comfort and satisfaction, as well as accessibility, can be used in a wide range of environmental conditions, favour sustainable use of resources,

respect sustainability life cycle principles, including end-of-life analysis involving the reuse of new and replaced elements at the end of service life;

- Consider renovation packages also integrating renewable energy sources for buildings with respect of the aesthetic, the historical value and/or the local architectural identity;
- Lead at least 3 large-scale demonstration of the solutions in diverse geographical areas, with various local environmental, social, and economic conditions;
- Where relevant, contribute to standardisation (e.g. recycled concrete CEN standard) and certification activities (e.g. guides for non-standard hybrid component assessment).

Solutions for an inclusive, resilient, sustainable and modern built environment

The following topics are being considered as the cross-cutting actions directly implemented under the co-programmed European Partnership B4P:

C5-D4-B4P-10-2022: Designs, materials and solutions to improve resilience, preparedness & responsiveness of the built environment for climate adaptation[58]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 5 and 7.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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.

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

- Increased awareness of the built environment's protective role for people and climate adaptation in case of disruptive events;
- Mainstreamed resilience as a key feature of the built environment across its life cycle;
- Improved ability of the built environment to support the preparedness and responsiveness to disruptive events at larger scales;
- Improved ability of the built environment to contribute to the overall quality of living and working;

[58] This topic was formerly C5-D4-B4P-15-2022.

- Strengthened supply chains for materials and solutions for a resilient and climate proof built environment, adapted to local risks.

Scope: The proposal should:

- Deliver innovative designs, materials and solutions to improve resilience and climate proofing of the built environment (in particular new and existing buildings) in a cost-effective and reliable manner;
- Ensure the proposed solutions cover a broad spectrum of natural risks and disasters, for instance natural disruptive events such as earthquakes, floods, heat waves, with a particular focus on extreme climatic events;
- Ensure the proposed solutions make use of natural, easy to manage, as well as advanced, evolutive materials and technologies that help combat the effects of global warming (increased cooling demand, heat island effects, etc.) and result in increased durability, resilience and adaptability of buildings and infrastructures, including their foundations;
- Develop and deploy digital and interoperable tools for monitoring, detection of, and response to critical situations (e.g. evacuation of people and first responders);
- Rely, where relevant, on self-sensing and adaptable materials, and materials with embedded sensors and actuators;
- Include, as part of the proposed solutions, built environment concepts that are self-sustained for a certain period of time – including off-grid electricity supply, green infrastructure and water purification and / or rain water provision in buildings;
- Where relevant, investigate whether and how the proposed approaches could apply to cultural heritage buildings across different typologies and geographic conditions, also including innovations in business models and ensuring holistic integration of disciplines across the value chain;
- Validate the proposed solutions for a set of locations that is coherent with the risks and disasters considered in the proposal, ensuring a high degree of awareness and involvement of supply chains;
- Demonstrate that the proposed solutions improve the protection of people when experiencing disruptive events and contribute to enhance resilience and climate proofing at a larger scale (e.g. district, city, energy system);
- Demonstrate that the proposed solutions contribute to improving the overall quality of living and working in the buildings (e.g. in terms of accessibility, comfort and well-being);
- Demonstrate cost-effective improvement of the energy performance, reducing the cost of the interventions compared to traditional methods, as well as the energy related operational costs after the renovation;
- Demonstrate that the proposed solutions improve 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);
- Lead at least 3 large-scale demonstration of the solutions in diverse geographical areas, with various local environmental, social, and economic conditions;

- Clustering and cooperation with other relevant projects is strongly encouraged; e.g. with the Horizon Europe Partnership on 'Driving urban transitions';
- 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;
- For this topic, projects are encouraged to define and implement ambitious international outreach and cooperation strategies.

C5-D4-B4P-11-2022: Solutions for the sustainable, inclusive and accessible regeneration of neighbourhoods enabling low carbon footprint lifestyles and businesses[59]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 5 and 7.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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 outcomes: Project results are expected to contribute to all of the following expected outcomes:

- Lasting behavioural change of people and economic actors towards lower carbon footprint lifestyles and businesses;
- Mainstreamed participatory planning processes and interaction with all relevant stakeholder groups in city planning;
- More sustainable, low emission, inclusive and affordable neighbourhoods and built environment;
- Improved accessibility of neighbourhoods through building-integrated, sustainable mobility solutions;
- Extended application of digital applications and tools to ease decision-making processes in complex stakeholder structures;
- Raised awareness and increased capacity of citizens on participatory processes for enhanced sustainability and environmental performance;
- Increased well-being and economic prosperity of citizens in a low carbon, sustainable built environment by ensuring high indoor and outdoor quality, and affordability of renovation solutions.

[59] This topic was formerly C5-D4-B4P-16-2022.

- Increased attractiveness of deep renovation through new regeneration and smart growth models for sustainable living;

Scope: The proposal should:

- Deliver innovative methods and solutions for the regeneration of neighbourhoods, with due consideration of, inter alia, energy efficiency, sustainability, health, inclusiveness and accessibility, based on participatory planning processes and innovative decision-making procedures and digital applications;
- Ensure the proposed solutions allow to identify and integrate local sources of raw materials for building renovation in built environment planning scenarios;
- Ensure the proposed solutions include new evidence-based approaches (e.g. strategies and digital tools) to help quantify the benefits of integrated built environment transformation aimed at climate neutrality;
- Ensure the proposed solutions allow for involving all stakeholder groups, including inter alia elderly people, those with reduced mobility and persons with disabilities, and households affected by energy poverty, also seeking to address gentrification issues in neighbourhoods affected by energy poverty;
- Ensure the proposed solutions include concepts for local renewable energy generation and consumption integrated at building and district level in combination with multi-modal mobility concepts targeted to both urban and rural neighbourhoods;
- Ensure the proposed solutions contribute to optimising energy balancing at local level (e.g. thanks to energy sharing platforms and services connected to local micro-grids and / or virtual energy markets, including demand response and decision-support systems and block chain applications);
- Ensure the proposed solutions comply with the principles of circular economy, favouring urban mining, efficient use of resources, durability, reuse and recyclability;
- Ensure the proposed solutions are developed taking into account local environmental, social, and economic conditions and are relevant for the different geographical locations targeted;
- Where relevant, include concepts for energy circularity such as waste heat recovery from local industries (or other sources) and use in nearby buildings or in low-temperature district networks and, valorisation of by-products and residues (e.g. from local agro-food industry) for energy or other uses;
- Where relevant, investigate whether and how the proposed approaches could apply to cultural heritage buildings;
- Lead at least 3 large-scale demonstration of the solutions in diverse geographical areas, with various local environmental, social, and economic conditions;
- Consider social innovation where relevant and in the case where the proposed solutions are at the socio-technical interface and require social change, new social practices, social ownership or market uptake;
- Facilitate awareness raising and capacity building of citizens and relevant stakeholders (e.g. citizen associations, local authorities, businesses from the relevant sectors) on the principles and multi-benefits of sustainable, inclusive and accessible built environment;

- Clustering and cooperation with other relevant projects is strongly encouraged; e.g. with the Horizon Europe Partnership on ‘Driving urban transitions’;
- 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.

C5-D4-B4P-12-2022: Sustainable and resource-efficient solutions for an open, accessible, inclusive, resilient and low-carbon cultural heritage: prevention, monitoring, management, maintenance, and renovation[60]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Increased availability and enhanced overall performance, including with regard to cost-effectiveness, of solutions applicable to the reliable and respectful historical renovation of heritage buildings, preserving their architectural and cultural identity;
- Demonstrated potential of sustainable, energy and resource-efficient historical renovation of heritage buildings;
- Better protection of the value and long-term inclusiveness, accessibility and usability of cultural heritage sites;
- More cost-effective and less disruptive modernisation and preservation of the heritage built environment;
- Enhanced prevention and monitoring of the heritage built environment;
- Leading role of the cultural heritage in deployment, showcasing and replication of solutions for a sustainable built environment.

Scope: The proposal should:

- Deliver innovative, sustainable, energy and resource-efficient solutions for the cost-effective improvement and preservation of cultural heritage built environment along

[60] This topic as formerly C5-D4-B4P-17-2022.

all relevant aspects: inclusiveness, accessibility, resilience, environmental and energy performance.

- Ensure the proposed solutions cover all relevant aspects of the heritage built environment's life cycle: design, renovation works, operation, monitoring and management, and maintenance;
- Ensure the proposed solutions allow to maintain the heritage value (e.g. artistic, historic, social and scientific) of targeted sites, while improving access and comfort of users and visitors, and reducing maintenance and operational costs;
- Ensure, where relevant, that the proposed solutions rely on (adapted) historic or traditional construction techniques and materials for sustainable restoration;
- Ensure the proposed solutions include natural low maintenance as well as advanced renovation techniques for high quality design and construction, including new digital technologies, while preserving the cultural value of the targeted sites;
- Ensure the proposed solutions contribute to facilitate the integration renewable energy sources while respecting the aesthetic and cultural identity of the targeted buildings;
- Ensure the proposed solutions contribute to the cost-effective improvement of the energy performance, also reducing the cost of the interventions compared to traditional methods;
- Ensure the involvement of relevant stakeholder groups (e.g. civil society organisations, associations, cultural heritage stakeholders) and citizens' acceptance thanks to co-creation processes;
- Deliver and demonstrate decision-support tools for low-disruptive, optimal renovation of heritage built environment to enhance sustainability;
- Clustering and cooperation with other relevant projects is strongly encouraged; e.g. with the Horizon Europe Partnership on 'Driving urban transitions';
- 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.

C5-D4-B4P-13-2022: Smart-grid ready and smart-network ready buildings, acting as active utility nodes[61]

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 6 and 9 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

[61] This topic was formerly C5-D4-B4P-18-2022.

Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

Expected outcomes: Project results are expected to contribute to all of the following expected outcomes from the grid and to adapt their behaviour accordingly;

- Improved interoperability and synergies between electricity and other energy carriers, and with other relevant non-energy sectors (e.g. mobility), supported by buildings, contribution to energy system integration at building's level;
- Improved competitiveness of buildings as flexibility assets for grid and network management

Scope: The proposals should:

- Deliver building-to-grid integration solutions that are cost-effective, simple to use and easy to install and maintain, and are applicable to both new and existing buildings;
- Enhance interoperability and synergies between electricity and other energy carriers (e.g. district heating networks, hydrogen, fuel cells, etc.) and where relevant, other relevant sectors (e.g. e-mobility);
- Enhance synergies between on-site energy storage and on-site renewable energy sources;
- Contribute to enhance interoperability in the modelling of electricity grids and buildings;
- Ensure the proposed solutions include 'big data' applications for real-time management and predictive maintenance of technical building systems;
- Ensure the proposed solutions do not have any negative impacts neither on the satisfaction of building users (e.g. in relation to comfort or accessibility) nor on the potential of circular material flows during the building's life cycle, and maximise potential benefits (e.g. energy costs savings and health)
- Ensure the proposed solutions give access to accessible, reliable and user-friendly tools with limited maintenance needs and, to relevant building (and grid / network) data for interested stakeholders (e.g. facility managers);
- Assess the contribution of proposed solutions to the enhancement of smart readiness of buildings as rated by the smart readiness indicator under Directive 2010/31/EU;
- Where relevant, rely on advanced monitoring and management solutions such as those that integrate digital models / BIM with energy modelling and simulation at building level and district level;
- Implement and demonstrate innovative and competitive balancing, storage and generation services in buildings, while ensuring building users' and occupants' comfort and satisfaction;
- Demonstrate cost-effectiveness and economic viability of the proposed solutions and underlying business models for both consumers / end-users and the economic actors involved;

- Demonstrate the use of large-scale interoperable platforms that bring together different actors and sectors (ESCOs, aggregators, DSOs, etc.) to exchange data and develop services;
- Seek to involve major European innovators in relevant fields (demand response, communications, smart appliances, building services, facility management, energy services, etc.) with limited experience of Horizon 2020;
- Clustering and cooperation with relevant projects is strongly encouraged; e.g. with the Horizon Europe Partnership on ‘Driving urban transitions’.

<u>Industrial facilities in the energy transition</u>

The main expected impacts are:

- Increased energy efficiency and reduced GHG and air pollutant emissions through recovery, upgrade and/or conversion of industrial excess (waste) heat, as well as electrification of heat generation in industry.

Please note that this topic focusses on thermal energy management in industry, while the bulk of R&I related to industry is in the scope of the Cluster 4 “Digital, Industry and Space”

C5-D4-IND-01-2021: Full-scale demonstration of heat upgrade technologies with supply temperature in the range 100 - 160°C

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of up to 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex D.

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

- Demonstration at full scale (0.5 – 10 MWth) of industrial heat upgrade systems to supply various industrial processes with useful heat in the (sink) temperature range of 100 – 160 °C, extracted from renewable heat sources (e.g. solar thermal), ambient heat or industrial waste heat .
- Improvement of the economic and technical performances of heat upgrade in order to cover more industrial processes.
- Demonstration of business models and contractual agreements in the cases of use of the upgraded heat within the industrial plant, in other neighbouring plants or heating networks, identifying also potential regulatory barriers

- Better awareness of the challenges and benefits of heat upgrade in the relevant industrial sectors

Scope:

This topic aims to satisfy the need for low temperature heat in the relevant industrial sectors, by upgrading lower temperature heat flows, including renewable heat sources, ambient heat or industrial excess (waste) heat, as a cost-efficient way to improve energy efficiency and reduce the GHG emissions.

Heat upgrade technologies exist, such as for example heat pumps, but their cost needs to be reduced, notably by improving their performances, and their operation needs to be demonstrated in various industrial contexts, in order to ensure their wide deployment. The optional integration of renewable heat sources (e.g. solar thermal) as the input heat flow to be further upgraded, is in scope.

In order to reach this goal all the following development areas need to be covered:

- Identify the target industrial processes which would benefit from this technology, as excess (waste) heat sources and as users (heat sinks); assess the impacts of these applications 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 applications in the subsequent optimisation and demonstration steps. A preliminary analysis of the technico-economic feasibility and impact of the proposed heat upgrade process is expected already in the proposal.
- Optimise the heat upgrade system to improve its economic and technical performances in terms of: sink output temperature range (100 to 160°C); temperature increase between sink inlet and sink outlet temperatures; temperature spread between source and sink temperatures; flexibility to source input temperature variations; higher sink thermal power; higher coefficient of performance; lower CAPEX (equipment) and operational costs (higher efficiency and lower maintenance).
- Development/improvement of design tools at components and system levels.
- Integration and long term full-scale demonstration of the system in industrial environment in at least one industrial sector.
- Technical and economical life cycle assessment of heat upgrade systems adapted for at least 4 industrial sectors, to demonstrate economic viability, define business cases and exploitation strategy.
- Assess the potential impact in CO2 emissions reduction (MtonCO2/a) and energy savings (TWh/a) in EU27 and (if data are available) in the Associated States, of using heat upgrade systems in the relevant industrial sectors, taking into account not only the thermal energy temperature and volumes needed by the relevant sectors[62], but also the temperature lift capabilities, and the availability of ambient or waste heat sources. The supply temperature ranges to be considered for the impact assessment are: <100°C, 100-200°C and >200°C. Evaluate the potential impact at global level by extrapolation.

[62] Including at least: Food & Beverage, Chemical, Pulp & Paper, Machinery, Non-metallic Minerals

- Identify the potential barriers to the deployment of heat upgrade and use due to the local regulatory framework in the EU Member States and Associated States.
- Disseminate the technical and economic benefits, notably (but not only) to the communities of the relevant Horizon Europe private-public partnerships.

Given the transversal nature of the technology, the potential for transferring the technology to the building heating sector, including district heat networks, should be assessed and disseminated.

C5-D4-IND-02-2022: Development and pilot demonstration of heat upgrade technologies with supply temperature in the range 150-250°C

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 3 million to 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

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

- Validate the technical feasibility of industrial heat upgrade systems capable of supplying various industrial processes with useful heat in the (sink) temperature range of 150 – 250 °C from renewable heat sources (e.g. solar thermal), ambient heat or industrial waste heat.
- Development and demonstration at pilot scale (5 – 200 kWth).
- Better awareness of the challenges and benefits of heat upgrade in the relevant industrial sectors

Scope:

This topic aims to satisfy the need for low-medium temperature heat in the relevant industrial sectors, by upgrading lower temperature heat flows, including renewable heat sources, ambient heat or industrial excess (waste) heat, as a cost-efficient way to improve energy efficiency and reduce the GHG emissions.

Available heat upgrade technologies, such as for example heat pumps, are limited to supply (sink) temperatures of 150°C. Innovative heat upgrade technologies have the potential to extend the temperature range up to 250°C, which would allow to cover more industrial applications.

In order to reach this goal all the following development areas need to be covered:

- Identify the target industrial processes which would benefit from this higher temperature heat upgrade technology, as excess (waste) heat sources and as users (heat sinks); make a preliminary assessment of the potential impacts of these industrial applications 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 applications in the subsequent development step; estimate by extrapolation the benefits at global level. A preliminary analysis of the feasibility and GHG emissions reduction impact, of the proposed heat upgrade process is expected already in the proposal.

- Develop one or more heat upgrade technologies to raise the sink output temperature to the range 150 to 250°C, if needed investigate in new refrigerants; optimise its technical performances in terms of: temperature increase between sink inlet and sink outlet temperatures; temperature spread between source and sink temperatures; flexibility to source input temperature variations; higher sink thermal power potential; higher coefficient of performance.
- Integration and demonstration of at least one system at pilot scale, in conditions, as far as practical, similar to real industrial environment. The optional integration of renewable heat sources (e.g. solar thermal) as the input heat flow to be further upgraded, is in scope.
- Make a preliminary estimation of the future equipment cost for at least two industrial applications, to evaluate its economic potential; define an exploitation strategy.
- Dissemination of the technical and economic benefits, notably (but not only) to the communities of the relevant Horizon Europe private-public partnerships.

C5-D4-IND-03-2022: Development of high temperature thermal storage for industrial applications

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 3 million to 4 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex D.

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

- Short term (intraday or a couple of days) thermal storage systems for decoupling the heat generation from the heat use in industrial processes.
- Development of new materials for heat storage dedicated to medium to high temperature industrial processes.
- Better awareness of the challenges and benefits of heat storage in the relevant industrial sectors

Scope:

This topic aims to satisfy the need for decoupling the heat generation from the heat use in continuous or non-continuous industrial processes, in order to allow for heat exchanges between different industrial processes and so enable industrial symbiosis, or to generate heat during off-peak times and so provide energy demand flexibility.

In order to reach this goal all the following development areas need to be covered:

- Cost effective and new designs for high temperature storage of industrial heat, with minimal footprint. The large capacity storages in combination with long design lifetime, require the development of novel materials and designs.
- Development of materials and components: thermal storage materials, container construction, insulation technology, heat exchangers with aid of computational fluid dynamics.
- Integration and demonstration of the system at lab scale.
- Make a preliminary estimation of the future equipment cost for at least two industrial applications, to evaluate its economic potential.
- Make an analysis of the potential industrial applications and related benefits of the proposed storage system in EU27 and (if data are available) in the Associated States and, by extrapolation, at global level; a preliminary version of this analysis is expected already in the proposal. Define an exploitation strategy.
- Dissemination of the technical and economic benefits, notably (but not only) to the communities of the relevant Horizon Europe private-public partnerships.

C5-D4-IND-04-2021: Industrial excess (waste) Heat-to-Power conversion based on organic Rankine cycles

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million to 14 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
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 outcomes: Project results are expected to contribute to all the following expected outcomes:

- Improved systems based on Organic Rankin Cycle (ORC) to achieve scalability to higher power levels, higher cost effectiveness, wider input temperature ranges, significantly reduced system size, allowing wider take up of heat recovery and its conversion to power from more industrial processes
- Better awareness of the challenges and benefits of systems based on Organic Rankin Cycles

Scope:

Better use of process excess/waste heat represents a significant source of energy savings for industries. The conversion of excess heat back to electricity would also improve energy efficiency, mitigate the increase of electricity consumption due to industrial electrification and thereby reduce the load on the power grids. This will also facilitate balancing the grid due to intermittent supply of electricity from renewables and so contribute to reduce GHG emissions.

Accounting for the results of previous research[63], proposals will integrate an industrial excess heat-to-power conversion system based on Organic Rankin Cycle (ORC) and demonstrate the system operation in industrial environment at an output power level of at least 2 MW, with improved cost efficiency compared to existing solutions

In order to reach this goal all the following development areas need to be covered:

- Optimisation of thermal cycles and mixtures of fluids or additives for different temperature levels of recovered heat and constrained industrial environment, in terms of efficiency and economics (capex, opex);
- Development/improvement of design tools at components and system levels;
- Development/improvement of materials and components: heat exchangers, turbomachinery (including advanced sealing technologies), waste heat recovery unit, power generator and electronics, etc.
- Integration and demonstration of the system in industrial environment; optionally heat storage can be integrated as well in the system;
- Technical, and economical life cycle assessment of heat-to-power systems adapted for at least 4 energy intensive industrial sectors, to demonstrate economic viability, define business cases and exploitation strategy;
- Evaluation of the potential impacts in terms of primary energy savings (GWh/year) in industry (heat recovery) and potential primary energy savings in the power generation sector, assuming full deployment in EU Member States and (as far as data are available for the calculation of the impact) in Associated Countries, and at global level by extrapolation.
- Dissemination of the technical and economic benefits, notably (but not only) to the communities of the relevant Horizon Europe private-public partnerships.

[63] EU co-funded projects I-Therm (680599), TASIO (637189)

Destination 5 – 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 CO2 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. The institutionalised Partnership on Transforming Europe's Rail System will play a major role in digitalising the sector towards integration in multimodal logistics chains. It will help to increase energy efficiency of the transport system by increasing the attractiveness of rail transport, thus enabling a modal shift for passengers and goods. Moreover, this partnership will also contribute to increasing the environmental performance of railways. Aviation partnerships are briefly described further below in the section on aviation.

Expected impacts at Destination-level and their link to expected impacts of the Strategic Plan

Activities under this Destination should set out a credible pathway for contributing to the following **Destination-level expected impacts** (more detailed impacts for each thematic area are elaborated in the introductory text of the thematic area):

a) Transformation of **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.

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 deep reduction of greenhouse gas emissions, and maintaining European aero-industry's global leadership position.

c) Accelerate the **development and prepare the deployment of low-carbon and clean solution in the shipping sector**, reduce its environmental impact (on biodiversity, noise, pollution and waste management), improve its system efficiency, enhancing digital and EU satellite-navigation solutions and contribute to the competitiveness of the European waterborne sector.

d) Devise **more effective ways for reducing emissions and their impacts** through improved scientific knowledge.

These Destination-level impacts will directly support the **Strategic Plan's expected impact** of *"Towards climate-neutral and environmental friendly mobility through clean solutions across all transport modes while increasing global competitiveness of the EU transport sector*

Zero-emission road transport

The mobility of people and goods is the essence of an integrated European single market, territorial cohesion and an open, inclusive society: it is the backbone of economic growth across the continent, enabling prosperity and employment. However, transport, mobility and their related services still need to improve their environmental performance. In addition, road transport is one of the major sources of pollutant emissions in cities, generating increasing concerns about the impact of road transport on human health.

The “Towards zero emission road transport” (2Zero) partnership will set an ambitious research programme to accelerate the development and to support the deployment of a zero tailpipe emission road transport with a system approach in Europe. It will develop a common vision and deliver a multi-stakeholders roadmap for a climate neutral and clean road transport system. It will improve the mobility and safety of people and goods, hence ensure future European leadership in innovation, production and services.

The transformation towards zero tailpipe emission road mobility will deliver tangible benefits including, at the local scale, pollutant emission reductions, cleaner air (including unregulated pollutants, nanoparticles and secondary pollutants), reduced noise, increased accessibility and more liveable urban plus peri-urban spaces. Further, major benefits for citizens’ health and quality of life will be generated, European economic growth will be supported, hence a solid base for new business opportunities will be created. Within 2Zero, one of the priorities will be given to the development of drivetrains for zero emission heavy-duty long-haul vehicles, where progress is lagging behind other sectors of road transport. On a global scale, the reduction of CO_2 and other GHG emissions will contribute to mitigating climate change.

Several levels of interactions are foreseen with other European initiatives, in particular with the Industrial Battery Value Chain (Batteries) and the Cooperative Connected and Automated Mobility (CCAM) co-programmed partnerships, plus Clean Hydrogen Europe (CHE), as well as with the Mission on Climate Neutral and Smart Cities.cities.

The main expected impacts are:

a) Accelerated uptake of zero tailpipe emission, affordable, user-centric solutions (technologies and services) for road-based mobility all across Europe; as well as user acceptance to improve air quality, the circular economy and to reduce their environmental impact (Topics C5-D5-ZERT-01-2022, C5-D5-ZERT-02-2021, C5-D5-ZERT-03-2021, C5-D5-ZERT-06-2022, C5-D5-ZERT-11-2022);

b) Affordable, user-friendly charging infrastructure concepts and technologies that include vehicle-grid;interactions (Topics C5-D5-ZERT-01-2022, C5-D5-ZERT-02-2021, C5-D5-ZERT-07-2021, C5-D5-ZERT-11-2022);

c) Demonstration of innovative use cases for the integration of zero tailpipe emission vehicles, and infrastructure concepts for the road mobility of people and goods (Topics C5-D5-ZERT-01-2022, C5-D5-ZERT-02-2021, C5-D5-ZERT-11-2022);

d) Life-cycle analysis tools and skills for the effective design, assessment and deployment of innovative concepts in road vehicles and mobility services, in a circular economy context (Topic C5-D5-BAT-ZERT-20-2021).

C5-D5-ZERT-01-2022: Modular multi-powertrain zero-emission systems for HDV (BEV and FCEV) for efficient and economic operation

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 15 and 20 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex D.

Expected outcomes:

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

- Demonstration of high efficiency long haul Heavy Duty Vehicle (HDV) powertrain for truck-trailer combinations, Vehicle Group 4, 5, 9 or 10 of VECTO capable of 750 km unrefuelled/unrecharged range whilst operating at maximum gross vehicle weight (GVW) of minimum 40 tons under operational conditions comparable to the VECTO long haul mission profile;
- Demonstration of the developed concepts over a period of at least 6 months in real world conditions involving manufacturer(s), energy provider(s), electric and hydrogen infrastructure and end users (e.g. carriers, logistics service providers and cargo owners) from across Europe, covering at least 500 km (for long haul) average daily operation in real conditions – in line with drive and resting time regulation;
- Provide fleet managers with ZEV-specific, flexible, managerial tools (e.g. adapted to the characteristics of vehicles and infrastructure) supporting the seamless integration of zero tailpipe emissions vehicles into fleets and facilitating the assignment of tasks and routes (infrastructure, range, charging time, payload etc .);
- Contribute to significant price reduction steps by targeting and showing a pathway towards total cost of operation equality with 2020 engine-based solutions assuming a production volume of >= 10.000 pieces/yr, and net TCO reductions beyond that.

Scope:

The call is asking for a modular and flexible powertrain approach for large heavy-duty trucks which can serve varying mission demands (range, power and re-charging/-fuelling requirements) by varying battery/tank sizes to serve different missions and driving profiles within one vehicle platform.

Flexible vehicle platforms can allow the installation of modular powertrain solutions including either pure BEV/FCEV versions or hydrogen FC range extended battery vehicles, exploiting the scalability and modularity of the installed power units to allow cost efficient solutions for dedicated missions.

At least two different prototypes must be demonstrated covering two different missions under operational conditions: one of which is mandatorily for long haul freight transport, as defined in expected outcomes, while the additional(s) prototype(s) shall be a truck-trailer combinations, Vehicle Group 4, 5, 9 or 10 of VECTO capable of at least 500 km unrefuelled/unrecharged range whilst operating at maximum gross vehicle weight (GVW) of minimum 40 tons under operational conditions comparable to the VECTO regional mission profile.

Applicants should go beyond activities carried out by actions funded under topic C5-D5-ZERT-02-2021, avoiding duplication of activities already performed under this topic, as well as of activities developed by ongoing Fuel Cell and Hydrogen Joint Undertaking projects[64].

Proposals are expected to address the following:

- Efficient energy/thermal management including the HVAC system and during ultra-fast charging both while driving and during breaks (including auxiliaries like overnight hotel and, optionally, refrigeration loads) achieving a minimum 44% energy efficiency in FC “charge sustaining mode” or 82% for BEV configurations (both at “tank-to-wheel” on the VECTO Regional Distribution and Long Haul cycles as appropriate);
- For FC applications, the scalable power level of a hydrogen-based power unit for full power operation or range extension to vary power and range demands of different mission profiles must demonstrate at least 90% availability and 30.000 hr FC operational life for safe and efficient operations, including scale-up options; (FC and tank development are excluded from this topic; suitable engagement with FCH projects needs to be foreseen);
- For BEV long haul applications, demonstration of fast charging concepts, capable of fitting established regulations and business practices, with a range recovery of at least 400 km in 45 min, with an overall charge efficiency of at least 80%. The proposed solutions shall not reduce transport productivity (i.e. km per day, including driver resting time) and shall be deployable at load/unload points and staging areas, while ensuring grid compatibility;
- Demonstration of a delivery load capacity not less than 90% of a current such vehicle;
- Improvement of inverter and DC/DC technologies integration in regard to optimized and novel cooling concepts and cost reduction, considering where appropriate synergies with C5-D5-ZERT-03-2021;
- Improvement of specific central, high power electric motors or modular in-wheel motor concepts, considering where appropriate synergies with C5-D5-ZERT-06-2022ZERT
- Achievement of cost benefits by optimization of the control architecture;
- Predictive maintenance strategies considering AI technologies, including deployment of prognostic and diagnostic techniques and control units in order to improve the lifetime of the fuel cells systems;
- Show the minimum achievable impact on environment (GHG, polluting emissions, biodiversity, resources etc.) using a comparative life-cycle assessment;
- 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 is produced as output from a ‘digital twin’ should be FAIR, deposition in relevant repositories should

[64] https://www.fch.europa.eu/page/fch-ju-projects

be encouraged[65]. Relevant data are required to be reported in the TRUST collection platform[66];

- Price reduction resulting from economies of scale due to modularity and standardization of components in other truck, bus/coach (and where possible railway) applications (also creating links with on-going projects in the FCH partnership) with a clear roadmap for how to increase production numbers after the end of the project and for developing the necessary value chains;
- Develop and validate tools for zero tailpipe emission vehicles integration in fleets (and mixed fleets) for efficient assignment of tasks (routes, charging strategies, assignments etc.);
- Identify European cross-border corridors with lower barriers or higher benefits to start market operations, along with possible future initiatives within the Connecting Europe Facility context.

C5-D5-ZERT-02-2021: Nextgen vehicles: Innovative zero emission BEV architectures for regional medium freight haulage

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 10 and 15 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex D.

Expected outcomes:

Projects' results are expected to contribute to all the following expected outcomes:

- Provide innovative, competitive and affordable zero tailpipe emissions vehicles architectures for regional medium freight transport and distribution full electric N2 and/or N3 category vehicles (VECTO vehicle group 1, 2 or 3), with prototype(s) fully validated for a zero-emission driving range of at least 200 km under driving conditions comparable to VECTO regional and urban delivery mission profiles, with strong synergies of urban and suburban operations;
- Demonstrate the vehicle's functionality and performance in real world conditions, with innovative freight transport and logistics use cases, at least matching the performance of non-zero tailpipe emission vehicles and maximising productivity in terms of usage (tn/km transported per year);

[65] Final Report and Action Plan from the European Commission Expert Group on FAIR Data, "TURNING FAIR INTO REALITY" - https://ec.europa.eu/info/sites/info/files/turning_fair_into_reality_0.pdf
[66] TRUST Technology Reporting Using Structured Templates (TRUST); details to be included in final draft

- Provide fleet managers with ZEV-specific, flexible, managerial tools (e.g. adapted to the characteristics of vehicles and infrastructure) supporting the seamless integration of zero tailpipe emissions vehicles into fleets and facilitating the assignment of tasks and routes (infrastructure, range, charging time, payload etc.);
- Demonstration of fast charging concepts capable of fitting established regulations and business practices, particularly at load/unload points enabling efficient operations;
- Optimizing the specific charging infrastructures for logistics hubs and TEN-T urban nodes;
- Contribute to significant price reduction steps by demonstrating total cost of operation parity with 2020 engine-based solutions, assuming a production volume of >= 10.000 pieces/yr and net TCO reductions beyond that volume;
- Contribution to increasing economies of scale, following demonstration of powertrain integration in different applications and the realisation of the necessary value chains.

Scope:

The action will focus on validation of full electric N2 and/or N3-category vehicle(s), specific regional, suburban and urban freight transport applications seamlessly integrated into fleets.

Proposals are expected to address all the following:

- Validation of N2 and/or N3-category zero emissions vehicle(s) demonstrating the capabilities of the proposed architecture in terms of range, payload, charging requirements, access to connected data etc.;
- Demonstration of high efficiency powertrains capable of at least 300 km range between recharging events, whilst operating with at their maxium allowed GVW;
- Demonstrate at least 200 km average daily operation in real conditions over a period of at least 6 months, according to different mission profiles and requirements including end users from across Europe;
- Achievement of total 10% improvement in overall efficiency over current generation electric vehicles of the same categories;
- Demonstration of a delivery load capacity not less than 90% of a current such vehicle;
- Define and develop charging infrastructure solution(s) and associated strategies (private, public or public-private) for the different use cases associated to logistics hubs and TEN-T urban nodes, also proposing an analysis of the minimum viable recharging stations European network, possibly also in coordination with projects issuing from 2Zero topics C5-D5-ZERT-07-2021;
- Development of specific powertrain components might be included where needed, considering synergies with C5-D5-ZERT-03-2021 where appropriate;
- Assess the capabilities under real operational conditions/use cases and propose strategies to overcome payload and range limitations (e.g. charging strategies while loading/unloading), exploiting all potential operational benefits (e.g. low maintenance and operational cost) as well as innovation enabled by big data acquisition, analysis, and usage to broaden the missions in terms of payload and daily running within the regional scope, and maximizing vehicle productivity (ton km per year) thus demonstrating value for fleet operators and end users;

- 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;
- Synergies with shorter range/lower payloads urban and suburban applications in the municipal waste collection or construction activities, can be included;
- 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 is produced as output from a 'digital twin' should be FAIR, and deposition in relevant repositories should be encouraged[67];
- Develop and validate tools for zero tailpipe emission vehicles integration in fleets (and mixed fleets) for efficient assignment of tasks (routes, charging strategies, assignments etc.).

C5-D5-ZERT-03-2021: Nextgen EV components: Integration of advanced power electronics and associated controls

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex D.

Expected outcomes:

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

- Demonstrate a minimum of 20% cost reduction of power electronic modules and inverters for a given power, to increase the overall affordability of EVs in mass production (in comparison to the cost of the best current-generation or close to market components at proposal submission time);
- Significant advancements in efficiency (reduction of losses by 25%) and thermal performance (increased maximum operational temperature), both parameters versus the state of the art of the targeted application. This allows further range increases, faster charging and easier thermal management of the whole powertrain, as well as possible improvement in cabin-heating and defrosting in winter;
- Facilitating the integration of power electronics in batteries and electric motors/axles (including modular approaches);

[67] Final Report and Action Plan from the European Commission Expert Group on FAIR Data, "TURNING FAIR INTO REALITY" - https://ec.europa.eu/info/sites/info/files/turning_fair_into_reality_0

- Increased reliability and availability of powertrain by intelligent control and diagnostics techniques, predictive maintenance of machine and inverter;
- Achieve automotive quality levels in the whole system with new, robust and reliable functionalities and materials.

Scope:

In the constant drive to improve efficiency and performance while increasing affordability, the recent introduction of wide bandgap (WBG) technologies (such as SiC, GaN and beyond, whose development is excluded in this topic since it is covered in the KDT partnership) need further effort for their integration in new, on-board architectures, taking into account new powertrain generations with different voltage levels, e.g. 400V, 800V and higher.

Achieving innovative compact integrated solutions will be both a strong lever for future economies of scale and a strong advantage for flexibility that will satisfy user's needs and increase acceptance, as well as an enabler for new powertrain architectures with distributed multiple wheel drive.

Proposals are expected to address all the following:

- System-partitioning/-integration: Intelligent, redundant and fail-safe topology/system architecture; highly integrated power electronics with component integration and building-block approaches for minimal level of parasitics; integration and functional modularity of power converters (integrated on-board charger and traction inverter, integrated inverter and electric motor, integrated DC/DC and inverter, high-frequency DC/DC power conversion with WBG components);
- Development of power electronics enabling drastic size and weight reductions for the electric drive, with significant advances beyond 5 kW/kg or 20kW/litre for a BEV;
- Circuit concepts and control: Topologies adapted to advanced WBG semiconductors and new materials, "including & beyond GaN"; control approaches for improved reliability as well as reduction of losses, noise and interference at a system level; novel control strategies with self-learning and intelligent monitoring capabilities, suitable for very high-frequency operation;
- Interconnected technologies: robust assembly and materials, better suited for integration and new power semiconductors, alongside the capability for higher temperatures and currents, as well as extension to 3D design;
- Joining and connecting technologies: Power output stages with low impedance connection and increased robustness against temperature cycling, as well as advanced interfaces for modular building blocks;
- Thermal management: Module and component concepts with improved thermal performance; concepts for integrating cooling in housings, assemblies and component groups, and with environmental control if appropriate; direct liquid-cooling for high power can be considered through different solutions such as direct cooling with an immersed power module, jet impingement and spray, microchannel heatsinks or heatpipes; extension of air-cooling up to medium power levels;
- Simulation/Prediction: Holistic simulation chain (e.g. along the value chain: Vehicle/ Motor/Electronics/IC); advanced physics-based simulation tools/models to increase development capabilities in order to close the gap to physical limits and reduce over-

engineering; prediction of functional availability dynamically during operation predictive maintenance;

- Gate Drivers: Working on the integration of the driver component with the power module is a suitable solution to limit the stray inductance between the gate driver and the semiconductor; the gate driver should allow maximum switching speed by dealing with electromagnetic interferences (EMI) to drive wide bandgap devices.

C5-D5-ZERT-06-2022: Nextgen EV components: High efficiency and low cost electric motors for circularity and low use of rare resources

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-7 by the end of the project – see General Annex D.

Expected outcomes:

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

- Lower cost, higher efficiency and power density electric motors for mass produced cars and vans, with a design-to-X approach enabling easy dismantling and recyclability and a reduced use of (rare) resources through the development or application of alternative materials or advanced configurations;
- Lower electric vehicles (EV) cost and improved range and, therefore, a wider market penetration;
- Improved motor design and development processes, considering a full product life-cycle assessment in a circular economy environment, for lower total energy and resources consumption;
- EU-wide job creation/retention by developing a world-leading design and production base, including supplying SMEs.

Scope:

Electrical machines are a fundamental part of zero emission powertrains for all classes of road vehicles, but the target of this topic is the core market (with powertrains of 50-120kW continuous power).

Proposals are expected to address all the following:

- Increasing primary efficiency, in particular by widening the high efficiency area and compactness, for example through topology or operational improvements, inclusion of increased features in integrated solutions, analysis of performance aspects over the machine-in-system life-cycle.
- Demonstrate the following specific targets (percentages with respect to automotive state of the art in 2020):

- o Continuous power densities >23kW/litre and >7 kW/kg or continuous torque densities > 50Nm/litre and >20Nm/kg, for the complete motor including its cooling, allowing global performance optimisation specific for the category and type of vehicle;
  - o A 20% reduction in losses during typical vehicle operation;
  - o A reduction in the use of rare resources by 60%;
  - o Unit cost for the complete motor at mass production levels (100.000 units/year) < 6€/kW;
  - o A recyclability rate >60%, or demonstrating the possibility of “functional” recycling of critical raw materials by repurposing magnets without extracting the single rare elements, thus keeping a higher share of the value;
- Increasing high system voltages offer new opportunities for readdressing the current versus voltage trade-offs, throughout the vehicle systems and in aspects of the recharging infrastructure, duly considering potential impacts;
- Guarantee the heat rejection of high energy density motors through multiphysics models in order an optimal design (use of rare resources, reduction in losses, high efficiency)
- Novel manufacturing process supporting increased integration, enabling, amongst other things, improved thermal control;
- The use of alternative architectures and materials to the currently used rare earths-based magnets and configurations recyclability plus life-cycle environmental impact aspects need to be considered, aiming at the best compromise with other performance parameters to reach the stated outcomes. If composite reinforced materials (CRM) are included in the design, the development of processes for the economic recycling of at least 60% of any rare materials must be included: only this additional work will justify the use of up to EUR 2 million of the expected EU contribution;
- The proposed motor concepts must comply with automotive standards, given the normal dynamic and duty-cycle requirements, reliability, EMC etc. The proposed concepts should consider the motor (integration of electronics the motor, excluding their development, which is covered in C5-D5-ZERT-03-2021), and intergration of any related transmission. The concept has to be validated through representative duty-cycle evaluation, as a minimum on the test bed or, optionally with minimum-change integration, on an existing vehicle;
- The provision of a digital-twin of the concept, in-line with current best practice modelling and simulation standards, is required.

C5-D5-ZERT-07-2021: System approach to achieve optimised Smart EV Charging and V2X flexibility in mass-deployment conditions

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 7 and 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5-7 by the end of the project – see General Annex D.

Expected outcomes:

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

- Definition of the optimal charging concepts for future "millions level" Electric Vehicles (EV) deployment in different environments;
- Development of smart charging strategies and control mechanisms that maximise the efficiency of whole energy system, the RES use, utilising and storage capacity, whilst minimising grid reinforcements and conventional energy generation needs as well as EV drivers' satisfaction, in terms of performance and cost (including vehicle cost and energy plus system tariffs);
- Innovative concepts, technologies and performances (installation cost, number of recharging points, recharging time, maximum power from/to the grid, etc) of affordable, user-friendly smart charging solutions, co-optimising the needs of EV users, of the house/building and of the supplying grid;
- A better understanding of the cost impact on the vehicle and on the charging infrastructure of different smart, bidirectional (V2X) charging approaches and technologies, including the cost of battery damage/degradation;
- Contribution to the integrated planning process of systems aimed at exploiting cross-sector mutual benefits (G2X and V2X);
- User-centric design criteria, metrics, methods and parameters, to assess and measure customer expectations and the satisfaction of EV drivers concerning smart charging solutions, as key success factors of EV-grid mutually beneficial charging experience;
- Demonstrate V2X potential in encouraging renewable energy growth through the integration with low power renewable energy sources (e.g. photovoltaics on the roof or in parking lots), by reducing energy exchange with the grid (in both directions) by 50%.

Scope:

Charging solutions are a fundamental building block of a full and effective shift to EVs. When scaled to a mass-market-level, current solutions, such as 'plug-'n'-charge', would create an extra burden on the power system. Mass availability of battery storage, provided by parked vehicles (in case they are plugged in the appropriate equipment), can, however, be turned into a clear upside if an integrated approach is adopted. Moreover, the effective exploitation of EV charging flexibility can minimise investments in the electric grids, resulting in reduced system charges for the network users.

Proposals are expected to address all the following:

- Improve the understanding of EV driver needs and behaviours (urban dwellers, businesses and city authorities), the quantity and quality of drivers' needs (e.g. range anxiety, duration and preferred time slot for charging, acceptance of incomplete charge levels), the conditions for allowing a shared control of battery State-of-Charge, and the availability to commit to vehicle utilisation limitations (rewards & penalties) as a starting point for designing smart charging solutions; integration and control solutions of the technology within the vehicle should also be considered, in view of achieving the best customer acceptance;

- Consider current slow/medium power charging, analyse and develop lower cost alternatives, appropriate for the mass deployment of V2X slow charging, considering both AC and DC solutions, related costs and issues (for instance power quality of AC systems), in view of optimising the cost of on-vehicle and infrastructure-side electronics;
- In particular, innovative scalable solutions for large parking areas and urban, on-road parking in smart cities, e.g. from a suitable central power system with multiple outputs to individual distributed low power chargers, shall be considered and developed;
- The alternative to performing periodic fast charging shall be analysed and its pros and cons defined, including the impact on the grid of a large number of fast chargers adequately spread (considering the potential of local storage), with a view to providing authorities with a complete perspective of the optimal infrastructure depending on local conditions;
- Trade-offs shall be performed in different EV penetration scenarios, with a view to defining the optimal balance between the vehicle and infrastructure costs, the location and typology of charging infrastructures, whilst demonstrating the efficiency of V2X centralized and decentralized scenarios and catering for different EV categories, in different environments. The following alternatives shall be considered: private, semi-public (i.e. in residential and business buildings), public covered or on-road parking, in cities with high or low private parking availability, for light and heavy duty vehicles, in cities or countries with monophase and triphase systems, integration with personal (V2H) or business power generation (V2B), participation to grid service markets (V2G), aggregation with other consumer/prosumer facilities, behind-the-meter energy optimisation for prosumers;
- A final assessment of the conditions in which full V2X functionalities are needed and beneficial, and where simple V1G charge control is sufficient, shall be performed;
- Develop optimal smart charging processes and protocols, minimising EV driver's costs by rewarding their charging/discharging flexibility via effectively exploiting the storing capabilities of EVs both in a planned way (charging in low cost/generation surplus time slots) and considering contingencies (fast response in balancing grids flows fluctuations). AI-driven energy management schemes shall be developed, including their market and regulatory frameworks (dynamic tariffs criteria and focused incentives), to be tested preferably through regulatory sandboxes. In this respect, the communication requirements among the energy actors shall be evaluated, promoting the interoperability (preferably at European level) between the proposed solutions;
- Clear framework for use of any personal data and data portability generated by the natural persons using the vehicle interface should be investigated thoroughly in line with the General Data Protection Regulation;
- Quantitative parametric and probabilistic models for assessing the impact of progressive, massive EV penetration on the electricity system shall also be established: these should consider modifications of hourly/weekly load profiles, conditions for energy adequacy (primary energy supply) and power adequacy (grid congestions/reinforcements);

- The impact of the different bidirectional charging profiles on the life of the EV battery and power electronics shall be quantified, used to define the damage cost and, therefore, the right level of incentives for the users in allowing their battery to be used;
- In order to achieve a seamless smart charging experience for the EV driver, the connectivity and interoperability between the vehicle and the different players in the EV charging ecosystem, including charging point operators, roaming platforms and DSO, together with access to all the necessary data to facilitate this objective, shall be promoted, This should help in creating an integrated mobility system, assisting drivers and passengers to take optimal decisions in selecting the charging points and overall trip planning, in terms of cost, waiting time, and the extra services provided to drivers and to vehicles. As a consequence, relevant data collection, exchange and management for communication protocols and user interfaces (including the need for new/updated standards) shall be assessed and developed as needed.

C5-D5-ZERT-11-2022: New generation of full electric urban and peri-urban buses (e-BRT) to strengthen climate-friendly mass transport

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 20 and 25 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex D.

Expected outcomes:

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

- Reduction of greenhouse gas and pollutant emissions as well as traffic congestion, by demonstrating the developed technologies and advanced Bus Rapid Transit (BRT) concepts in European and in developing countries'partner countries cities;
- Development of next generation innovative effective public transport systems concepts using full electric buses (M3[68]) through electrified Bus Rapid Transit (e-BRT);
- Present efficient, economically viable and flexible, integrated solutions of e-BRT within existing mass transport networks (all modes) and with personal mobility solutions (walk, bike, powered two-wheelers, cars etc.);

[68] Category M3: motor vehicles designed and constructed primarily for the carriage of passengers and their luggage with more than eight seating positions in addition to the driver's seating position and having a maximum mass exceeding 5 tonnes

- Develop innovative, integrated, infrastructure solutions combining charging, bus-stops and dedicated bus lines, for both urban and peri-urban road networks;
- Development of flexible bus transport, end-user solutions, for both urban use in dense city centres and for less populated peri-urban environments, meeting future user demands of convenience, efficiency, safety and security;
- Development of an international market for European e-BRT solutions, in particular, in countries with low offer of public transport with challenging conditions (climate, environment, poverty, etc.).

Scope:

The scale-up phase of clean and intelligent city buses should cover the most demanding routes, by switching the longest, fastest and busiest routes to electricity. Therefore, the investment in innovations in city buses (e.g. clean propulsion) can be optimized through BRT systems, as the operations can be planned, mileage is known and energy requirements can be predicted on-board since the roads and distances are familiar. As such, revisiting the concept of BRT with new, enabling technologies and solutions offers a key opportunity to reduce the carbon footprint of the transport sector, particularly in cities.

Demonstration and testing in real operation shall be developed in four or five different European cities and at least one city in a partner country in a developing context either in Africa or in CELAC countries (Community of Latin American and Caribbean States). The demonstration activities should include mega-cities, larger/smaller cities and the link to peri-urban, inter-urban and sub-urban dwellings in order to afford complementary solutions in test and demonstrations. Zero tailpipe emission buses and their related infrastructure shall be applied in BRT lines, in different city contexts, together with the needed integration of e-BRT with other mass-public transport systems, and with personal mobility solutions. Solutions include both the physical vehicles and the overall services offering.

Proposals are expected to address all the following:

- Electrification combined with automation and connectivity enablers[69], to optimize and validate the whole advanced BRT system;
- Operational concepts: increasing the capacity use rate; the average commercial speed; punctuality / regularity;
- Synchronization with other city transport modes[70]; service quality whilst reducing CO2 emissions, and cost per km/passenger;
- Replicability: use of the e-BRT technology under environemental, infrastructure and social conditions different from the European ones.

The focus of projects must be on mass transport, full electric Bus Rapid Transit (e-BRT) systems using full size buses (M3). Vehicle, infrastructure and operational aspects have to be addressed, considering charging systems for stationary, opportunity[71] and Electric Road

[69] g. big data, cloud computing, artificial intelligence
[70] e.g. metro, bike-sharing, ferry
[71] e.g www.oppcharge.org

Systems (ERS) for buses (wireless, contact, SRS etc.) and strategies (IMC, Opportunity at stops or terminal, offline charging etc.).

Proposals must take into consideration the transport operators' and transport authorities' needs for financial viability, effectiveness, flexibility, environment conformance, safety and security. The impact of e-BRT technologies on bus performance and on the frequency of necessary repair and maintenance work, the life duration of the bus, and the costs that have to be covered at the end of the life (recycling; upgrading etc.) might have a huge influence on the financial side and should, therefore, also be covered.

In line with the strategy for EU international cooperation in research and innovation, international cooperation is encouraged.

C5-D5-BAT-ZERT-20-2021: LCA and design for sustainable circularity - holistic approach for zero-emission mobility solutions and the related battery value chain (Joint call BAT-ZERT)

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 4 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Coordination and Support Action

Expected outcomes:

The project addressing this BAT-ZERT Joint Call shall approach a commonly accepted Life Cycle Assessment (LCA) of zero-emission road transport solutions, focussing on zero-emission vehicles and their batteries, as one of their central components, as well as other applications of the same types of battery cells (e.g. industrial, stationary applications etc.).

Proposals shall foresee coordinated activities on LCA and Life Cycle Inventory (LCI) at vehicle and cell levels, to define and develop a unique and shared approach with common methodologies for both zero-emission vehicles and the battery value chain. The project's main governance (e.g. Steering Group, Advisory Board) shall foresee direct involvement of relevant stakeholders from the automotive and battery sectors, as well as relevant EC services (in particular DGs JRC, RTD, CLIMA, ENV and GROW).

The project's results are expected to contribute to all of the following expected outcomes:

- A consensus concept for a harmonised, robust, transparent and real-data based LCA approach and tools (also with consideration for extension to social Life Cycle Assessments, S-LCA), with an emphasis on light-duty and heavy-duty zero-emission vehicles (ZEV) and batteries; enabling the assessment of the sustainability performance and evaluation of optimal designs along the value chain and over the full life-cycle (cradle-to-cradle), also taking into account the need of comparing with conventional solutions;
- New, holistic and applicable quantitative tools to drive an approach to the design of ZEV, their components and batteries;
- Take into account in particular uptake of the Renewable Energy both for manufacturing processes and for information to the end users;

- A harmonised strategy for sustainability by design, describing requirements and specifications of tools for all life-cycle phases required to improve the environmental performance of ZEV and batteries, including their components and sub-systems;
- A commonly accepted ontology for a European-wide LCI database for zero emission vehicles and batteries, including all sub-systems and components, and using real data for the present and short-term future, whilst using provisional data, based on trajectories for the reduction of GHG emissions in the Power, Industry and Transport sectors, and use cases, including pre-defined data quality indicators;
- Greater environmental sustainability and lower TCO (total cost of ownership) through consistent and frontloaded real-data based assessment of technologies and solutions, with extension to other sectors using the same cells and technologies;
- Alignment of on-going harmonisation and standardisation activities relevant for a road transport-specific LCA approach, with emphasis on ZEV and the related battery value chain;
- In line with existing or upcoming legislation, and based on guidance from the EC, agree on the common access to the database, including, where this could be necessary for the Member States to inform their policies;
- Increased awareness and acceptance of a European-wide, battery and road transport-specific LCA approach and LCI database.

Scope:

In order to make the best, most informed choices in terms of sustainability, it is of utmost importance for zero emission road transport to have the right tools to assess technologies, non-technical measures and product life cycle processes in a holistic way. In selecting the right technologies for clean and sustainable mobility at a system, vehicle and component level, the ecological footprint and the impact of technologies upon society have to be assessed, based on highly reliable data at an early stage of development and planning in a harmonised and comparable way.

Proposals are expected to address the following:

- Elaborate a consensus LCA (and S-LCA) approach specific for zero-emission solutions, with an emphasis on light-duty and heavy-duty ZEV and the related battery value chain, suitable for the full life-cycle (cradle-to-cradle) whilst expanding the existing complexity of an environmental LCA to assess and compare the impact of solutions in a holistic way, and reflecting the needs of a resource-efficient circular economy;
- Screening, collecting and evaluating existing LCA and S-LCA needs, methodologies, tools datasets and metrics, to identify and overcome knowledge gaps, to identify development needs in current methodologies and tools, as well as to identify the impact reduction potential for ZEV and batteries;
- Elaborate the baseline for a Europe-wide, commonly accepted, road transport sector LCA approach and LCI database for ZEV and the related battery value chain, based

on real data or on provisional data based on trajectories for the reduction of GHG emissions in the Power, Industry and Transport sectors, ensuring openness, accessibility and transparency, implementing the FAIR data principles[72], whilst ensuring applicability to existing technologies;

- Taking into account existing and upcoming legislation, under policy guidance of the EC, define access to the database, for purposes of policy makers, including to the authoritites of the Member States, where appropriate;

- Promote the uptake of Renewables in manufacturing processes and information on renewables to the end usersHarmonise across all stakeholders for methodologies, tools, datasets and metrics as well as for target criteria, to help improve consistency, robustness and transparency, and to address important gaps in transport-specific LCA and LCI, with focus on ZEV and the battery value chain. It is of utmost importance to involve all stakeholders, including the EC services, Member States and standardisation bodies, to ensure the acceptance and succeeding implementation of the LCA approach and LCI database;

- Conceptualise the frontloading of a LCA and S-LCA for ZEV and the related battery value chain, at an early stage of development and planning, in a harmonised and comparable way, ensuring the compatibility and comparability with (conventional) alternatives;

- Definition of use cases for ZEV and batteries, representative of real-world conditions (e.g. for activity, lifetime, impacts linked to the specific duty-cycle and accounting for user behaviour) and the exemplary characterisation and calculation of impacts from zero-emission vehicle components, through applying the consensus LCA approach, and assessing the variability inherent to key real-world parameters;

- Elaborate the potential and outline the transfer of the consensus LCA and S-LCA for other applications, such as fuel cells or stationary battery systems, or markets such as aerospace or maritime;

- This work should build upon both recent existing EC- and stakeholder-funded research (such as the eLCAr project and the reports “Circular Economy Perspectives for the Management of Batteries used in Electric Vehicles” and “Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA”[73], aiming at aligning ongoing activities within this context towards a single LCA approach.

[72] Final Report and Action Plan from the European Commission Expert Group on FAIR Data, “TURNING FAIR INTO REALITY” - https://ec.europa.eu/info/sites/info/files/turning_fair_into_reality_0.pdf
[73] “Circular Economy Perspectives for the Management of Batteries used in Electric Vehicles” (Hill, N., Clarke, D., Blair, L. and Menadue, H., Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-10937-2 (online), doi:10.2760/537140 (online), JRC117790); “Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA” (Hill N. et a., 2020, DG CLIMA),

Aviation

Aviation, the climate and the economy are all inherently global and interlinked. Aviation's global economic impact, before COVID-19, was more than €2.4 trillion per year, while the European one was more than EUR 700 billion per year. The European economic benefit from aviation contributes to European prosperity and allows the EU to invest in climate neutrality and societal challenges. Beyond the economy and National security, aviation is also significantly contributing to the European social integration and Single Market. However, the environmental impact, although in absolute terms small, it is projected to increase towards 2050, if action is not taken now. The impact of aviation to environment and climate is driven by long-term effects (several years to hundreds of years) from CO_2 emissions and shorter-term ones (several hours, days, weeks or years) from non-CO_2 emissions (mainly from water vapor, NOx, SOx, soot, contrails and contrail cirrus). The CO_2 effects are well understood and are proportional to the fuel used. The non-CO_2 effects are still poorly understood and carry large uncertainties. Further research efforts are needed in this area. In 2017, CO_2 emissions from aviation represented 3.9 % of EU GHG emissions. It has been estimated that the non-CO_2 radiative forcing effects may be as much as 2-4 times those of CO_2. Finally, aviation contributes adversely to air-quality and noise.

Under business as usual projections and continued improvement of conventional technologies, GHG emissions are expected to grow substantially in a 2050 perspective, which is not compatible with the goals of the Paris agreement. It is therefore essential to accelerate technological innovation in the area of aviation, developing and commercialising novel low and zero carbon aircraft propulsion technologies and fuels. Until ultra-clean transformative aircraft propulsion and novel architectures will revolutionise aviation, energy efficiency, increased aircraft performance and sustainable drop-in and non drop-in fuels are high short and mediumterm priorities. The technological improvements should be further accelerated, without underestimating the efforts made so far. Over 10 billion tonnes of CO_2 were saved since 1990 through a combination of new technologies, operational efficiencies and infrastructural improvements, including airlines spending €1 trillion on over 12,200 new aircraft since 2009.

The proposed European aviation R&I in Horizon Europe will follow a policy-driven approach along the two main priorities (i.e. climate neutrality by 2050 and digital transformation) and implemented in three streams of activities:

1. A European Partnership Clean Aviation (EPCA) focused on three clearly identified paths, as described in Strategic Research and Innovation Agenda (SRIA). It should aim towards accelerating the development, integration and validation of climate-neutral aviation technologies (TRL 4-6), for earliest possible deployment.
2. A collaborative aviation R&I focused on transformative low-TRL (1-4) technologies. It should aim towards precompetitive fundamental aviation research and technologies for future development, validation and integration activities, in line with climate neutrality by 2050 and the new Industrial Strategy for Europe. Activities will include medium/long-term climate-neutrality technologies, local air-quality, non-CO_2 climate impacts, noise, digital transformation, integrated design and manufacturing, mobility, air-transport system, emerging threats (e.g. cyber, spread of communicable diseases), operational safety and new business models, exploiting synergies from space and defence. Links between the collaborative program and education will be further strengthened. Finally, the collaborative program will support EU policies, integrate EU aviation R&I stakeholders (e.g. ASD, ACARE, EUROMART, T&E, citizen's groups on noise) and develop further techno-economic assessments and decision

making tools, taking into consideration EU economic - transport – energy – climate - environment policies, infrastructure and R&I investments.

3. A European Partnership for Integrated Air Traffic Management focused on solutions that will support evolving demand for using the European sky, increased expectations on the quality of ATM and U-space service provision, transforming and optimising how ATM and U-space services are provided as well as accelerating market uptake. The focus of the IATM is on digitisation, automation and Artificial Intelligence.

While further alignment between the three streams will be performed, all propulsion technologiesthat consider integration at engine level will be developed exclusively in EPCA.

The **main expected impacts** of the Horizon Europe aviation R&I are:

- Disruptive gains by 2035, with up to 30% reduction in fuel burn and CO_2 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) ;
- Disruptive technologies entering into service by 2035 as well as 2050, based on new energy carriers, hybrid-electric architectures, next generation of ultra-high efficient engines and new aircraft configurations;
- New technologies for significantly lower local air-pollution and noise;
- Increased understanding of aviation's non-CO_2 climate impacts, enabling R&I activities to more effectively contribute to the EU's climate targets;
- Maintain global competitiveness and leadership of the European aeronautics industry and the whole aviation ecosystem, including modernization of Air-Traffic Management by leveraging space-based services;
- Protect the passenger and increase the resilience of the aviation ecosystem to external shocks (e.g. health issues, manufacturing, operations, cybersecurity);
- Deliver an 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.

C5-D5-AVI-01-2021: Greenhouse gas aviation emissions reduction technologies towards climate neutrality by 2050

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 2-6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 2-4 by the end of the project – see General Annex D.

Expected outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Deliver transformative technologies that will substantially reduce non-CO_2 emissions. The selection of technologies should be compatible with operational procedures and aligned with a potential inclusion of non-CO_2 emissions in EU and International aviation market-based measures (e.g. EU Emissions Trading System and ICAO CORSIA) and other potential relevant policy tools.
- Deliver transformative technologies for aircraft engines, systems and structures that will maximise the life cycle environmental impact reduction.
- Explore new modular aircraft configurations, optimised for the lowest possible environmental impact and noise footprint at take-off and landing operations, allowing 24/7 operations.
- Deliver improved aircraft performance technologies (including engine, hybrid-electric systems, management systems, light-weight multi-functional materials and structures), compatible with aviation climate reduction operational-mitigation strategies, in areas with high climate cost. The selection of technologies should deliver intermediate benefits and bridge the aviation climate neutrality gap towards 2050.

Scope: The impact of aviation to environment and climate is driven by long-term effects from CO_2 emissions and shorter-term ones from non-CO2 emissions (water vapour, nitrogen oxides, sulphur oxides, aerosols, contrails and contrail cirrus). The CO_2 effects are well understood and are proportional to the fuel used, while the non-CO_2 effects are still poorly understood and carry large uncertainties. The total climate impact of aviation is estimated to two to four times higher than the effect of CO_2 emissions alone (ref. International Panel of Climate Change - IPCC). R&I activities in Horizon Europe will pay adequate attention to CO_2 and non-CO_2 emissions, as well as their interdependencies.

Regarding the reduction of full-flight fuel burn and CO_2 emissions, the selection of technologies should have a holistic approach to aviation ecosystem, considering aircraft (including engines) technologies, improved air-traffic management solutions (input and synergies with ATM partnership), new fuel options (input and synergies with hydrogen partnership) and operational improvements. Timely alignment with European medium-term industrial roadmaps (beyond 2030) should be established.

Regarding the reduction of aviation non-CO2 emissions, the selection of technologies and operational measures should consider climate optimised flight trajectory planning avoiding sensitive areas, should be compatible with operational procedures and aligned with a potential inclusion of non-CO_2 emissions in EU and International aviation market-based measures (e.g. EU Emissions Trading System and ICAO CORSIA).

A potentially high risk in pursuing transformative and disruptive climate neutral aviation technologies is the recent evidence (last decade) from not as flawless as expected entry into service of innovative propulsion and aircraft technologies at large. To mitigate this risk, the R&I actions proposed in this topic should profit and linked with more integrated design and manufacturing advancements that are covered in topic 5-03-04-2021 (digital transformation).

Overall, this topic aims for new low TRL technologies for reduced life-cycle GHG emissions that will reach TRL4 by 2030, at the latest. The topic has synergies with the EPCA and Integrated ATM partnerships. All activities higher than TRL 3 that address the reduction of GHG aviation emissions, with emphasis on propulsion technologies and their integration, will be dealt in the European Partnership on Clean Aviation (EPCA). The low-TRL technologies in this topic may enable expand the design envelope with new configurations,, more electrified aircraft and engine architectures, more integrated metallic, composite and multifunctional aerostructures, advanced flow control and high-lift aerodynamics as well as advancements in flight control systems. To enable effectively addressing the non-CO_2 climate impacts, the topic will also support research to fill gaps in their understanding, and thereby enable addressing these impacts.

C5-D5-AVI-02-2021: Next generation digital aircraft transformation in design, manufacturing, integration and maintenance

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 3-6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 2-4 by the end of the project. However, exceptionally for this topic, activities may arrive upto TRL 6 in well-justified cases in coordination with the EPCA WP. – see General Annex D.

<u>Expected Outcomes</u>: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Deliver transformative digital technologies that will allow flawless entry into service of future European aircrafts (including engines, structures and systems) of all platforms. The outcomes should be in-line with technologies for future climate-neutral aircraft configurations and their integration (aligned with topic 5-03-02-2021). Multi-disciplinary model-based digital twins that cover the complete aircraft lifecycle, scaled-prototypes, representative rigs and unique research infrastructures fall within the expected outcomes.
- Advance further technologies that will enable flexible integration of simulation ecosystems in an extended enterprise context and allow multi-disciplinary design, optimisation and uncertainty quantification at realistic time-scales for commercial aviation.
- Deliver new technologies and methodologies for model-based validation and certification, measurement and prediction of software reliability for commercial aviation, new standards and alternative methods of compliance. Ensure compatibility between EASA-FAA working groups on standards (e.g. APR 4754/ED-79, DO 178/ED-12 and DO-254/ED-80).
- Reduce the lifecycle greenhouse gas impact of aircraft materials (including rare earth elements) and explore the fastest path towards their economical substitution. Advance further recovery and recycling methods in order to extend the useful life of materials, reduce the carbon footprint and produce new high-qulity parts for new applications.
- Deliver transformative digital and eco-efficient manufacturing technologies, advance further composite manufacturing, maintenance-repair-overhaul (MRO) and health

assessment processes and procedures that will allow flawless entry into service and continuous airworthiness of European aircrafts of all platforms. Optimised manufacturing and MRO processes and tools, as well as on-board and on-site sensors and communication platforms are within the expected outcomes.

Scope: This topic is about a real digital transformation with a holistic approach for the aviation ecosystem.

This topic aims to accelerate the design and manufacturing processes (including additive) as well as allow flawless entry into service of new aircrafts. The topic is in-line with the European new industrial policy and will bring even closer together the European supply chain (including innovative SMEs and start-ups). This topic may cover all aspects of digital aircraft, from design and manufacturing to operations and recycling. Digital-physical scaled demonstrator aircrafts for education, research and development are within the scope of this topic. Digital factory for all tiers and integrators and for all aircraft platform, from components to final assembly line (FAL) are also within the scope of this topic. As software becomes a vital part of the aircraft, new digital methods, tools and certification processes are of outmost importance. Synergies with the European High Performance Computing platform and European Digital Twin initiatives should be exploited.

C5-D5-AVI-03-2022: Towards a silent and ultra-low local air pollution aircraft

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 2-5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 2-4 by the end of the project – see General Annex D.

Expected Outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Deliver transformative technologies that will allow a step change in the reduction of local air quality (LAQ) from NOx, SOx, volatile organic compounds (VOCs) and particulate matter (PM) that occur below 900m above ground level around airports. Explore synergies with land-based energy systems in Destination 3 and 4 of this Work Programme for the capture of these emissions and/or purification of air.
- Deliver transformative technologies towards a silent aircraft operations around airports.
- Advance further integrated and reference European models and methods for estimating aircraft emissions (LAQ and noise) inventories for operations in the airport vicinity, highly accurate estimations on the number of people affected. The models, methods and advancements in measurement technologies should advance further, contribute to and collaborate with existing ICAO CAEP and EUROCONTROL initiatives. They should also be aligned with H2020-ARTEM outcomes towards meeting the ACARE Flighpath2050 goals.

Scope: LAQ and noise aviation emissions effect the quality of life and health. Air pollution is the number one environmental cause of premature death in the European Union. Despite progress in recent decades, it still causes more than 400,000 premature deaths every year, and it brings respiratory and cardiovascular diseases to millions.

While the aviation contribution is estimated to 0.4% of the total deaths attributed annually to global air quality degradation, aviation has a substantial impact on local air pollution around airport areas and efforts are ongoing to reduce it further. Aircraft noise remains a matter of concerns for airports and local authorities despite significant improvements, due to anticipated increase of total number of flights in Europe (could reach 12.8 million by 2035 – despite the present COVID-19 disruption).

Regarding the reduction of local air quality (LAQ) from NOx and particulate matter (PM), the selected technologies may consider sustainable drop-in and non-drop-in fuel options, aligned with EU industrial roadmaps and R&I activities in topic 5-03-02-2021.

Regarding the reductions of aviation noise around airports, the selected technologies should consider propulsion and aircraft-propulsion integration interdependencies as well as operational air-traffic management procedures.

This topic aims to support the EU and ICAO LAQ and noise policies. This topic aims for new aircraft and engine technologies that satisfy the design and operational interdependencies between CO_2, non-CO_2 and noise emissions, are compatible with approved operational procedures and are aligned with the European industrial roadmaps for further development, validation and integration beyond 2030.

C5-D5-AVI-04-2022: Digital aviation technologies for new aviation business models, services, emerging global threats and industrial competitiveness

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 2-5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 2-4 by the end of the project – see General Annex D.

Expected Outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Transformative digital aviation technologies that will enable new European business models and products (e.g. Urban Air-Mobility (UAM), seaplanes) with minimal environmental impact and opportunities for European competitiveness.
- Transformative digital aviation and space technologies as well as Unmanned Aircraft Systems (UAS), that will enable new services with pronounced societal impact for intermodal and multimodal transport, search and rescue operations, fast response to natural disasters, freight, firefighting, high altitude earth data-services, agriculture and forestry.

- New aviation products and services that exploit Artificial Intelligence and have pronounced impact to productivity, efficiency, automation and cost reduction.
- Breakthrough technologies that will minimise the risks from emerging global threats (cybersecurity, COVID-19) as well as increase the resilience of aircraft systems from increasing frequency of extreme weather conditions (e.g. temperature change, wind patterns). Technologies that address applications in difficult to access areas, including the open sea emergency response, avalaches, landslides and floods are within the scope of the topic.
- Transformative and breakthrough technologies that exploit synergies with aviation, space and defence. The development of materials and components for high-power density electrical arrchitectures at high altitude environment (e.g. cabling, insulation, power electronics) are within the scope of this topic.

Scope: On 10 March 2020 the Commission presented a new Strategy to help Europe's industry lead the twin transitions towards climate neutrality and digital leadership. Europe needs industry to become greener, more circular and more digital while remaining competitive on the global stage.

The topic aims to enable new digital aviation technologies for new aircraft business models and services, (e.g. EGNSS-based search and rescue, urban air-mobility, firefighting, AI-based technologies, digital data platforms) as well as minimise the risk from emerging threats (extreme weather phenomena, cybersecurity, COVID-19 communicable diseases) to aviation. Synergies with other EU initiatives should be exploited towards European digital platforms that deliver insights and analytics for citizens, businesses and decision makers.

C5-D5-AVI-05-2022: European Aviation Research Policy in support to EU policies and initiatives

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 0.5-2.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action – Support Actions – Procurements
Technology or societal readiness level	Activities are expected to achieve TRL 2-4 for the Research and Innovation actions by the end of the project – see General Annex D.

Expected outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

- Deliver at mid-term of Horizon Europe an update of European aviation R&I roadmap, while ensuring the alignment with the EU regulatory framework.
- Deliver a coherent framework and toolbox for technology and policy assessment of the impact of EU aviation research – with emphasis to GHG emissions, local air-quality and noise. Ensure coordination with EPCA, IATM, HFC, ACARE and ASD, taking into consideration the work perfomed in the CS2 Technology Evaluator.

- Support EU Member States towards a coherent update of ICAO standards that will prevent backsliding.
- Connect better EU aviation R&I with education and skills.
- Communicate the EU aviation R&I to citizens and stakeholders.
- Strengthen ERA in Aviation R&I, assess the R&I needs of European SMEs and promote aeronautics/aerospace spin-offs in all aspects of life.
- Strengthen the synergies between all aviation-relevant R&I activities in Horizon Europe.

Scope: In 2021, the European R&I will operate in a new European and global political context, with a new EU budget, new policy priorities, and a new R&I programme. As the Commission moves away from program implementation, while works much closer with Member States, a new European aviation research policy framework is necessary. This aviation WP is a representative example that aims towards EU policies and priorities (European Green Deal and new European industrial policy).

The European aviation research policy aims to contribute with science-based informed decisions that will bridge the gap between R&I, regulatory framework and economic investments (with emphasis on climate neutrality by 2050 and European competitiveness). The European aviation research policy also aims to connect better EU aviation R&I with education and skills as well as communicate the EU aviation R&I to citizens and stakeholders.

Enabling low-carbon, clean, smart, and competitive waterborne transport

The European Green Deal refers to the need to achieve clean, climate neutral shipping and waterborne operations and to the importance of research and innovation in this respect. Waterborne transport remains an important emitter of GHG and the sector needs to step up its efforts on a significant scale and through a wide range of measures. Within the International Maritime Organisation (IMO) global agreement was reached in 2018 to cut total shipping GHG emissions by at least 50% by 2050 compared to 2008 (baseline). The EU considers this too timid and is committed to a much higher level of ambition. By the same date the Union aims to cut all transport emissions by at least 90%. To provide the innovations needed to achieve this target and show global leadership (also in pushing far more ambitious global regulatory standards) a new focused “Zero Emission Waterborne Transport” co-programmed partnership (ZEWT) is proposed which will mobilise resources and leverage private and public investments towards the central objective of demonstrating by 2030 the deployable solutions needed for all main types of waterborne transport to become “net zero emission” by 2050 at the latest. This partnership will provide for the core activities of the waterborne transport part of this work programme and will consequently absorb the largest part of the available budget. This concentration of efforts is essential for the delivery of the over-arching EU policy objectives and the Horizon Europe Key Strategic Orientations “clean, sustainable, competitive, secure, safe and smart mobility” and “EU global industrial leadership and strategic autonomy in key technologies” for the waterborne transport area. Focus will be on functioning technical approaches through demonstrators and real world solutions meeting ambitious reduction and efficiency targets in key areas and at early cut-off points. Aside from disruptive research and innovation, also necessarily coming from new players and stakeholders, already existing zero-emission solutions will be scaled up with the aim not only to create lighthouse projects but also convince market participants that ambition can be matched with business sense.

Given that ships have a rather long life cycle and in light of the age structure of the current commercial fleet radically improved vessels must enter the market within the next ten years on a significant scale to meet the 2050 target date and the necessary emission reduction level. Gradual improvements and efficiency gains will not be sufficient. Therefore, relatively high TRLs will be sought. Projects under ZEWT partnership topics are expected to provide up to two presentations on progress made to the ZEWT partnership members, also with the aim to support the monitoring of the ZEWT partnership performance as well the necessary underlying development to make these achievements possible within the time frame of the partnership.

Solutions close to the market will help the European maritime technology sector (which is also a global key supplier of advanced solutions) to further improve its industrial competitiveness and secure employment for its highly skilled work force which remains a key EU economic policy objective.

Furthermore, in the context of the EU's digital strategy "A Europe Fit for the Digital Age" the waterborne transport sector will have to embrace a wide-ranging digitalisation, resulting in new business patterns, smart ports, automation of shipping and cargo handling (which will provide higher efficiency and significantly safer operations), autonomous vessels, and new design and decision tools.

Actions will also support resilience and recovery post COVID-19 which has particularly impacted the passenger shipping sector which is critical for the European waterborne industry, the European economy and coastal regions, and which has played a dynamic role in European tourism in recent years.

Topics in the waterborne transport part of this work programme are addressing these challenges with the aim to support all pertinent EU policy objectives.

The **main expected impacts** resulting from the expected topic outcomes in the three waterborne transport work programme areas of climate neutrality and protection of the marine environment [impacts a) – e), topics 1–6 and 8-14], digitalisation [impacts f) and g), topics 7 and 15], and industrial competitiveness [impact h), topic 16] are:

a) Increased and early deployment of climate neutral fuels and significant electrification of shipping, in particular and foremost in intra-European transport connections;

b) Increased overall energy efficiency and drastically lower fuel consumption of vessels (important in light of more expensive alternative fuels for which the sector will have to compete with other transport modes);

c) Enable the innovative port infrastructure (bunkering of alternative fuels and provision of electrical power) needed to achieve zero-emission waterborne transport (inland and maritime);

d) 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;

e) Strong technological and operational momentum towards achieving climate neutrality and the elimination of all harmful pollution to air and water;

f) Achieve the smart, efficient, secure and safe integration of maritime and inland shipping into logistic chains, facilitated by full digitalisation and automation;

g) Enable fully automated shipping (maritime and inland) and efficient connectivity;

h) Competitive waterborne industries, including the globally active European maritime technology sector, providing the advanced green and digital technologies which will support jobs and growth in Europe.

C5-D5-WAT-01-2021: Enabling the safe and efficient on-board storage and integration within ships of large quantities of ammonia and hydrogen fuels

Conditions related to this topic	
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve at least TRL 6-7 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Expected Outcomes:

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked ("*") whilst supporting the overall medium and longer term objectives:

- Contribution to the establishment by 2027 of at least two full scale demonstration projects using or potentially using 100% climate neutral fuels in a realistic shipping environment.
- Enabling the timely transition to climate-neutral ship operations by facilitating the wider adoption of carbon-neutral alternative fuels at a large scale and for shipping distances of 3000 nm or more.
- Supporting 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.
- *Demonstration of the feasibility to store and use hydrogen based fuels (generally in liquid form) on a medium and large scale (capacities equivalent to +300 tons of conventional marine fuel [HFO, MGO or MDO]) in a realistic environment on-board.
- *Demonstration of the use of these fuels in high power applications with long autonomy.
- *Demonstration of the applicability, in particular with respect to short sea shipping, IWT vessels, and the stricter environmental expectations for passenger ships.
- *Development of pertinent technical rules.

Scope:

Commercial shipping, including deep sea shipping (intercontinental maritime transport), short sea shipping (services between European destinations), and other ship operations with high power demand (which may include also certain aspects in IWT), requires the storage of large amounts of energy with conventional fuel capacities from hundreds to thousands of tons allowing operational autonomy up to several months. The use of sustainable alternative fuels at scale embracing a number fuel options needs to be studied and solutions developed for a wide range of applications.

Sustainable hydrogen, ammonia and other hydrogen derived fuels are potentially promising alternative fuels to make shipping fully climate neutral and independent of fossil fuels. Only very limited experience with the use of ammonia and hydrogen as fuel in a maritime environment exists today.

Hydrogen and ammonia are particularly challenging in terms of on-board storage capacities, storage methods, safe handling, space constraints and the structural integration of tanks, and their subsequent use in high power propulsion systems.

The aim is to develop large and very large storage solutions for hydrogen and ammonia (e.g. compressed H2, liquid H2, LOHC, hydrides, ammonia derived compounds) and their integration on-board. Whilst a certain fuel neutrality is sought a rigorous preselection of the most suitable type and form of fuels is required in order to come to a realistic demonstration environment as early as possible.

Research and innovation is needed with respect to the efficient and safe on-board storage and use under real shipping conditions, taking into account aspects such as pressure, temperature, explosion risk and toxicity. These aspects have to be investigated considering all the relevant issues related to the maritime environment such as structural response of the ship, ship motions and related effects (e.g. sloshing, resonance), corrosion, etc.. In order to facilitate the wide-spread use of these clean fuels solutions must be modular with the possibility of upscaling, and pertinent technical rules must be developed.

Solutions are not necessarily limited to maritime freight transport if it can be shown that these fuels can be used economically and efficiently at the specific scale of passenger services (ferries) and IWT. This may imply different regulatory constraints and infrastructure (bunkering) situations which have to be taken into account.

Projects will address both the storage of hydrogen and ammonia at capacities exceeding the equivalent of 300 tons of conventional marine fuels in order to show the use in a realistic environment with practical range and autonomy, although the fuel capacity may be adapted to the requirements of different ship types in a first stage of development. The scope extends to the design, testing and overall assessment of on-board systems for these fuels, developing concepts and testing them at lab scale with a robust perspective of scaling up to achieve the levels needed for operational commercial vessels. The structural integration of fuel and energy systems on-board, related safety issues, supporting standards development, and the minimisation of storage volumes and distributions systems towards the energy converters will be addressed. This must also take into account bunkering situations as part of the fuel handling on-board.

For the purpose of technology monitoring and progress against the state-of-art, but also to identify how each of the projects contribute to reaching the targets and indicators set by the Commission's Communication "A Clean Planet for All", and the European Green Deal, all actions related to hydrogen and fuel cells funded under this topic shall report directly or indirectly on an annual basis in a secure online data collection platform[74] managed by the Clean Hydrogen Joint Undertaking. The reporting shall consist of filling in the template questionnaire(s) relevant to the project content (and the technology development and TRL). This should be integrated as specific annual deliverable in the grant agreement. The template questionnaires can be consulted online (http://www.fch.europa.eu/projects/knowledge-management), subject to modifications due to technology development and/or change in projects portfolio.

Transport of such fuels in dedicated carriers will not be addressed.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-02-2021: Enabling the full integration of very high power fuel cells in ship design using co-generation and combined cycle solutions for increased efficiency with multiple fuels

Conditions related to this topic	
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 15 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Expected Outcomes:

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked (“*”) whilst supporting the overall medium and longer term objectives:

- Establishing the basis for achieving TRL 8 in on-board use of high power fuel cells by 2030.
- *Feasibility and technical demonstration of the use of high-power fuel cells in co-generation and/or combined cycle mode in waterborne transport.
- *Proof of scaling up, to a target of significantly above 3 MW power output, of fuel cell installations for shipping applications, including main propulsion of a short sea shipping or inland navigation vessel.

[74] Currently being the tool TRUST (Technology Reporting Using Structured Templates)

- *In case of a fuel cell using fossil fuel as input proof of significant efficiency gains (at least 20%) in a realistic environment compared to the conventional use of the fuels (e.g. within an ICE) with consequent reduction in GHG emissions.
- *Demonstration of the exploitation on-board of waste thermal energy produced by high temperature fuel cells in ship-specific applications (e.g. hot water, steam production, HVAC, etc.) for potential mass-market application.
- *Showing a realistic pathway to the wider use of fuel cell technology in waterborne transport including the assessment of the maturity and resulting mid-term potential of various fuel cell systems. This may include an initial focus on lower power propulsion applications in inland navigation where power reserves for adverse sailing conditions are less relevant.

<u>Scope</u>:

The use of fuel cells (FC) for waterborne applications is becoming increasingly relevant as stack power increases and the problem of the storage of un-regulated alternative fuels is solved. Demonstrating and upscaling this technology will lead to initial and earlier applications in IWT and short sea shipping vessels, as well as to complementary power generation on-board ships with high power demand, whilst also setting foundations towards deployment within even larger scale long distance applications.

Whilst previous projects have addressed applicability of mainly smaller fuel cell systems on-board, the full integration of very high power fuel cells on-board large ships represents a major challenge.

The total efficiency of high temperature FCs (e.g. HT PEM, SOFC, MCFC), using a variety of fuels, can be substantially increased through their use within a combined cycle, recovering secondary heat or using them in combination with secondary combustion systems. Whilst such installations are operating on land with substantial improvements in energy efficiency compared to an internal combustion engine, a fully integrated dual cycle multi-MW FC system has yet to be achieved on-board a ship. Regardless of the fuel used efficiency improvements would be expected to substantially contribute to climate neutrality as well as moving towards high power 100% hydrogen operations.

The aim is to prove the use of high-temperature FCs in a co-generation and combined cycle mode, either on a ship powered uniquely by FCs, or on-board a large ship with high power demand together with other power and thermal energy generation and management systems. Solutions need to address comprehensively the complexity of ship integration, e.g. the balance of plant components, batteries for dynamic loads and waste heat recovery systems.

A demonstrator of a high-temperature system as a large efficient unit will be developed and installed on-board a suitable vessel, and the budget foreseen reflects this ambition. The power of the FC will aim to exceed significantly 3 MW. The system may be run with conventional fossil fuels, with the use of an internal reformer. In this case the system needs to show a significant efficiency gain in terms of reduced GHG emissions compared to the conventional use of the fuel. Overall, the superiority of a FC solution over conventional ICEs should be demonstrated in a comparable arrangement. This may include an IWT application with less power to show the early marketability of the concept and its applicability on a large scale.

Initial target applications are those where the existing regulatory framework facilitates the introduction of a prototype which may depend on the sector of application, the ship type or the fuel used. The project will address the propulsion architecture and/or the electric system, it will not address the development of new FCs per se.

For the purpose of technology monitoring and progress against the state-of-art, but also to identify how each of the projects contribute to reaching the targets and indicators set by the Commission's Communication "A Clean Planet for All", and the European Green Deal, all actions related to hydrogen and fuel cells funded under this topic shall report directly or indirectly on an annual basis in a secure online data collection platform[75] managed by the Clean Hydrogen Joint Undertaking. The reporting shall consist of filling in the template questionnaire(s) relevant to the project content (and the technology development and TRL). This should be integrated as specific annual deliverable in the grant agreement. The template questionnaires can be consulted online (http://www.fch.europa.eu/projects/knowledge-management), subject to modifications due to technology development and/or change in projects portfolio.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-03-2021: CSA identifying waterborne sustainable fuel deployment scenarios

Conditions related to this topic	
Type of action	Coordination and Support Actions
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 0.5 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Expected Outcomes:

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

- A full understanding of clean fuel scenarios for different regions including sensitivity analysis of the different variables, consideration of evolving technologies and their applicability to maritime transport, inland navigation and waterborne operations.
- Development of quantified and dynamic techno-economic models for the uptake of sustainable fuels in a variety of waterborne application cases and for a range of regional conditions, clearly identifying uncertainties and parameters to enable technical and economic viability.
- Support for the transposition of RDI results into commercial and regulatory reality.

[75] Currently being the tool TRUST (Technology Reporting Using Structured Templates)

- Support to identify the impacts on ports (e.g. bunkering supply and other services, also for IWT, emissions measuring and verification), derived for the defined scenarios for different regions.

Scope:

Other than for short distances, waterborne transport is expected to become climate neutral mainly by the introduction of alternative, sustainable, and carbon-neutral fuels, by massive efficiency improvements and through related technologies for the fuel's use in propulsion and power generation on-board.

However, the uptake of specific alternative fuels in different European waterborne segments and geographical areas will vary and depend on fuel costs, fuel availability (generation and distribution), national or regional incentives, international co-operation, and many other fixed and dynamic factors. Whilst some studies addressing fuels for maritime transport and/or inland navigation exist, a proper characterisation per segment and per area including sensitivity and variability analysis has not yet been addressed.

Supporting decision making within the ZEWT partnership the CSA will identify and monitor the evolution of different sustainable alternative fuel deployment scenarios, taking into account different types of services, the evolution of sustainable fuel supplies, operational costs and capital expenditure, environmental factors (in particular those affecting coastal and port communities), as well as distribution and infrastructure implications relevant to the sector. Evolving and potential market mechanisms, regulations (e.g. the integration of the maritime transport sector in the ETS, the FuelEU Maritime Directive etc.) and incentives are to be considered. Discussions with sustainable fuel suppliers and facilitating the timely commercial deployment of partnership outcomes to accelerate climate neutrality and emission reduction of shipping are tasks of the CSA.

A model will be developed considering the wider aspects of waterborne transport (incl. IWT, short and deep sea shipping, high-tech vessels) involving energy and waterborne stakeholders, with an approach that is neutral with regard to specific energy carriers or technologies. Focus will be on the cost-efficient and timely deployment of solutions on a large scale and the potential evolution of these factors over time. A life cycle assessment should be included and linkages or synergies with alternative fuel use in other transport modes should be explored.

Activities will be undertaken in close and formal cooperation with the H2020 STEERER project which is identifying strategic technological paths and priorities towards climate neutrality as well identifying business model evolutions. Therefore, the budget of this CSA is reduced. The project will support the waterborne community in the identification of market trends with a systematic approach to future scenarios, understanding of uncertainties and critical factors.

The project will liaise with EU and international bodies and their initiatives with respect to future fuel scenarios and emission control governance (e.g. FuelEU Maritime, ESSF, IMO) and will establish contacts with the main associations of fuel suppliers.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-04-2021: Innovative on-board energy saving solutions

Conditions related to this topic

Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Expected Outcomes:

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked ("*") whilst supporting the overall medium and longer term objectives:

- Proof of gains in vessel energy performance and operational efficiency through demonstrators that are applicable to maritime transport and/or inland navigation.
- Significant reduction in GHG emissions from waterborne transport.
- Enabling the timely on-board application of innovative and green solutions for energy transformation that require significantly higher volumes for storage and equipment.
- *Deliver at the end of the project deployable energy efficiency solutions (stand alone or in combination, for new builds and for retrofitting) with at least 10% energy savings compared to best available technologies for stand-alone solutions and at least 20% for combined solutions, each on the level of the vessel.

Scope:

The transformation of maritime transport and inland navigation towards climate neutrality can be accelerated through the development and deployment of innovative technologies to improve energy efficiency. The wide-spread adoption of these technologies, in particular for high-power vessels, is crucial. RDI efforts will develop technological solutions for higher efficiency, reducing fuel consumption as well as increasing performance. The overall aim is reducing the vessel's energy demand, facilitating the transition to sustainable energy sources with lower energy density and potentially higher cost.

Energy efficiency measures may have specific applications linked to new technologies (e.g. alternative fuels, fuel cells, electrification, assisted wind power propulsion) which require significant changes in the on-board energy balance and management.

Projects must address technological solutions for energy efficiency yielding at least 10% reduction in energy consumption compared to best available technologies for similar applications in case of a single measure and at least 20% in case of combined measures.

A wide range of potential solutions may be proposed, including for example: reducing thermal, electrical and propulsive loads, optimisation of on-board energy management systems, design based systemic/holistic approaches and/or the use of active/adaptive technologies.

Digital solutions supporting operational strategies and remote monitoring and control can also be addressed if they are contributing to higher energy efficiency. More and advanced sensors integrated with advanced energy management can form the basis for an increased full life-cycle ship energy efficiency and can feed into digital twin models for the ship and for its sub-systems. Cyber security aspects must be taken into account.

Other potential solutions may include waste heat recovery systems, HVAC improvements, new hull forms, advanced propeller and appendages for enhanced hydrodynamics, reduced hull resistance through air lubrication, new automation and control strategies, new coatings, employing new high performance materials (in particular lightweight materials such as composites) or enhanced production processes.

To maximise the potential for GHG reduction, solutions will be prioritised that are applicable to a wide variety of waterborne operations (and not just selective cases), regarding both maritime and inland navigation.

The technical and operational transferability will be ensured through standardisation and the development of multi-media documentations and training programmes enabling also the long term development of skills.

Activities addressing efficiency gains through the design of internal combustion engines or power generation systems are excluded.

Solutions are expected to be demonstrated in line with the expected TRL but testing within an operational environment would be a benefit.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-05-2021: Hyper powered vessel battery charging system

Conditions related to this topic	
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve at least TRL 6-7 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 7 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

<u>Expected Outcomes:</u>

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked (“*”) whilst supporting the overall medium and longer term objectives:

- Faster turnaround times of battery electric ships and facilitating the charging of larger on-board batteries.
- New business models are developed for electrical ships and their port operations in close cooperation with land side stakeholders.
- Increase Europe’s technological lead in fast charging systems for batteries that can be applied to a wide range of vessel types in the medium term.

- Increase Europe’s competitive advantage within the electric shipping market supporting jobs and growth.
- *At least two full scale demonstrators in two European ports showing the practical use for an end-to-end service between these ports (without a proprietary solution, the system must be compatible with charging in other ports as well).
- *Demonstration and performance assessment in a realistic environment of fast multi-MW recharging systems, leading to an increase in the technical and economic viability of battery electric shipping.
- *Market analysis and feasibility assessment of the more wide-spread deployment of fast high power electrical charging of vessels in European ports (or at certain offshore facilities), including short sea vessels and ferries.
- *Demonstrated flexibility regarding different waterborne applications to be served by the same connecting facility.

Scope:

Electrification is an important means to make waterborne transport climate neutral and is already successfully deployed within diesel hybrid ships and fully electric ferries serving shorter distances. The capacity and range of electric vessels are increasing and the cost of batteries are coming down. Due to comparatively high capital costs, business models of electric ships are often founded on high availability, reduced maintenance and fast turnaround.

The provision of high charging powers is often impeded by the lack of availability of high power fast charging and of an adequate electrical supply infrastructure in ports or ferry terminals. The provision of such infrastructure to enable (parallel) multi-MW charging can substantially increase the costs to deploy electric shipping services. Furthermore, charging infrastructures are usually bespoke to a particular electric vessel design. This lack of standardisation further hinders the deployment of electric ships of all types.

Focusing on the ship and shore side interface, R&I will deliver solutions and technology to minimise high power recharging times at port, explore the applicability of charging solutions to a variety of batteries and their usefulness for different ship types. R&I will develop standard interfaces which ensure a seamless integration of different electric ships into conventional port and ferry terminal operations, including their integration with future port and energy infrastructures as they evolve.

Projects will address technologies and solutions for minimising time-to-recharge, by ensuring a recharging system of at least 5 MW capacity. No specific type of connection (either physical or inductive) is preferred.

A high level of charging performance is expected being suitable for new vessels, but solutions should also be adaptable towards existing or refitted vessels.

The following aspects need to be addressed: Ease and required connection time, flexibility regarding power levels and energy transfer whilst minimising impacts on electrical grid infrastructure (cables, switchboards, etc.), addressing potential battery degradation during fast charging, impacts on materials through e.g. corrosion and thermal stress.

Substantial progress beyond the state of the art should be achieved, such as with respect to the Horizon 2020 E-Ferry project. Applicability should be towards a range of vessel types, with larger battery systems and longer autonomy.

It should be explored whether the results can be adapted to a range of particular charging situations where power demand may be lower but the resilience of the system has to be higher and the connection may be more difficult to make. For example, vessels serving wind parks or offshore installations may be able to benefit from direct and distributed charging at the park or installation to enable longer periods of fully electric operation increasing operational efficiency and eliminating excessive transit times.

The energy supply at the port side will not be addressed. However, projects must consider overall feasibility and constraints on the land side and assess the EU market demand for recharging stations.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-06-2021: Assessing and preventing methane slip from LNG engines in all conditions within both existing and new vessels

Conditions related to this topic	
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 7 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Expected Outcomes:

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked ("*") whilst supporting the overall medium and longer term objectives:

- Ensure that the transitional deployment of LNG fuel does not increase GHG emissions but maximises its potential to contribute to climate neutrality.
- Strengthening the European leadership in LNG technologies, allowing for a transitional sustainable use of LNG where it is beneficial.
- *At least one full scale demonstrator for full methane slip abatement for a vessel in operation.
- *Development and practical demonstration of technical abatement solutions both for retrofitted vessels and new builds, covering a range of operational scenarios.
- *Where still necessary and duly justified quantification of methane slip founded upon both in-situ measurements and consolidated pre-existing validated test results in the public domain addressing a range of LNG engine types and load factors, including dynamic loads as, for example, encountered in manoeuvring.

Scope:

Nearly all commercial vessels in operation today have a power generation based on one or more Internal Combustion Engines (ICE). Directive 2014/94/EU on the Deployment of Alternative Fuels Infrastructure defined minimum requirements for the building-up of alternative fuels infrastructure e.g. for natural gas. Currently Liquefied Natural Gas (LNG - methane) is an alternate viable marine fuel deployed to substantially reduce ship-borne pollutant emissions.

However, the impact of LNG on greenhouse gas emissions is strongly influenced by “methane slip”, including the release of unburnt LNG from LNG-fuelled ICEs. This is a problem that is being tackled but not fully solved.

Since methane is a greenhouse gas 84 times more potent than CO2 on a 20 year basis, the potential release of unburnt methane substantially increases the fuel’s impact on climate change. Whilst it is known that operations under some engine loading conditions and with some engine types can significantly increase methane slip, there is a lack robust data on the scale of the challenge for the existing LNG fleet and for new vessels.

Projects will address the current state of the art and the scatter of emissions between different types of LNG-powered engines. Operational data on methane slip from existing engine installations will be assessed, compared and made available. Activities may include additional measurement campaigns of methane slip where necessary and duly justified, addressing the complexity of different engine types at different load factors (including highly dynamic loads) and operational profiles. Activities will lead to a better understanding of the parameters involved in order to develop the most efficient abatement strategies through ICE improvement and/or post-treatment technologies. Such activities must go significantly beyond existing measuring campaigns and provide distinctively new knowledge. A repetition of measurements already made by producers of large marine engines will not be funded.

Project(s) will develop and demonstrate such strategies and the corresponding technologies for better performing ICEs and/or after treatment systems which virtually eliminate methane slip in all conditions in refitted or newly built vessels. By developing technologies also suitable for retrofitting this action will also have an impact on the existing LNG-powered fleet whilst ensuring that negative impacts on energy efficiency (potentially resulting in higher CO2 emissions) and on the suppression of pollutant emissions (in particular NOx) are avoided.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-07-2021: Digital Twin models to enable green ship operations

Conditions related to this topic	
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 7 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

<u>Expected Outcomes:</u>

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

- Reduced emissions and improved efficiency enabled through development of digital models and tools for a wide range of vessel types, ship systems and operational environments.
- Prove and quantify the impact regarding emissions reductions and improved efficiency through productivity and performance increases based on a proven and efficient environmental impact assessment methodology.
- Ensuring the wider applicability of digital models for different ship types, both for new constructions and for retrofitting, through a comprehensive methodology and a transferable system architecture.
- Proving the interoperability of data models between different ship types and regarding the link with port digital twin models.
- Benchmarking efficiency improvements against other industry sectors.
- Increase the confidence of investors concerning the expected improvements in energy efficiency and reduced emissions resulting from upgrades and modifications for both new designs and retrofitting.
- In the medium term, enable the development of the “zero emission decision support system” as a contribution to the 55% reduction goals of fuel consumption in 2030.

<u>Scope</u>:

The digital revolution is affecting most industrial sectors, enabling the digital modelling of designs, manufacturing processes and operations. A wider and better development of Digital Twin (DT) models enables new functionalities for the design and operation of vessels to improve operational efficiency to be developed and validated with increased confidence without resorting to more costly physical testing. DT modelling can be founded and validated using sensor data, data mining and merging, big data, AI and self-learning to improve efficiency on all levels. Such developments increase owner confidence in the expected performance when procuring innovative green systems as well as providing operational feedback to the manufacturer which can be used to further improve energy efficiency. In this respect DT models are understood as wide-ranging tools with known application areas and those still to be explored.

The waterborne (transport) sector is characterised by very diverse requirements and market realities. Ships, their systems and related technical and commercial processes are already widely using digital technologies including virtual models but those are generally developed individually and with significant overlaps. Capital expenditure is often very high. The wider implementation and integration of digital technologies into more coherent Digital Twins on-board and onshore supporting user oriented decisions is still in its infancy.

Whilst simulation environments are relatively mature maritime system tools, development to enable full exploitation of the potential functionalities is still lacking.

Activities will address the DT concept in order to improve energy efficiency and environmental performance from the early design phase of vessels to the end of the life cycle, thus providing assurance to the owner or operator concerning the expected improvements resulting from upgrades and modifications. This will be a key factor to achieve the zero-emission targets for waterborne transport, while increasing the understanding of vessel performance in a wide range of operations, in particular in the view of the parallel uptake of a multitude of innovative technologies for on-board energy storage, distribution and conversion as well as those for voyage optimisation and manoeuvring. A methodology to assess environmental impacts and performance improvements through the DT model should be developed and validated, with the definition of KPIs orienting the design choices and manufacturing processes.

Project(s) will develop DT models, preferably based on existing specifications and simulation environments, addressing different ship systems (e.g. engine and machinery operations, hull/propeller performance and interaction models, electric network management including in particular HVAC, cargo handling) in order to have a significant impact on energy efficiency as well as on operational performance, both in maritime transport and IWT and with regard to newbuildings and existing vessels. To this end the dynamic use of real life data (feedback loop) must be addressed as well.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-08-2021: Proving the feasibility of a large clean ammonia marine engine

Conditions related to this topic	
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve at least TRL 6-7 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 10 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Expected Outcomes:

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked (“*”) whilst supporting the overall medium and longer term objectives:

- Contribution to at least one full scale demonstrator with the ammonia-fuelled marine engine used in a commercial vessel for main propulsion by 2027.
- In the medium term, enabling operations for maritime intercontinental transport (tankers, bulk carriers, container ships) and realisation of bunkering infrastructures, depending on fuel availability scenarios.
- Enable the timely transformation of the existing maritime fleet towards climate neutrality through retrofitting of existing vessels with ammonia-fuelled engines.
- *Demonstration and validation of an ammonia-fuelled marine engine with power output in the +10 MW range. The validation shows safe and reliable operation in realistic scenarios and for a range of load cases.
- *In case of proven feasibility pathways to the uptake of ammonia as a marine fuel for deep sea shipping and high power vessels are set out.

- *Analysis of pathways to ammonia as a marine fuel through the establishment of regulations and solutions for health and safety issues.

Scope:

Deep sea shipping (maritime intercontinental transport) and ship operations with very high power demand require the storage of large amounts of energy carriers aboard in order to ensure the required autonomy and the ability to navigate safely in adverse and extreme conditions. The use of low energy density green fuels will in these operational environments lead to a significant loss of cargo volumes or useable space (e.g. passenger cabins) which directly impacts the economic parameters of the vessels and consequently leads to reluctance by ship owners to invest in clean ships.

Ammonia is a zero carbon fuel, with a (slightly) higher volumetric energy density than liquid hydrogen and with comparatively high liquefaction temperatures and pressures. Due to this, and its combustion characteristics, green ammonia has been widely advocated as a potential sustainable alternative marine fuel. Yet its possible use within a large low-speed marine engine has yet to be proven. A practical and easy use of ammonia may be a game changer in making shipping climate neutral, in particular if it can be used in the existing fleet through retrofitting.

The aim is to develop, demonstrate and validate a multi-cylinder internal combustion engine of at least 10 MW power output running on ammonia as its main fuel, with IMO-Tier III or lower NOx emissions and negligible emissions of SOx, particulates and other harmful substances or odours. As an indication total tank-to-wake GHG emission reduction versus an MGO baseline should be at least 80% (taking into account that the climate-neutral upstream supply of ammonia is not part of this topic). Risks should be assessed and the engine should also comply with all relevant safety rules and regulations as stipulated by classification societies and flag states.

Projects should demonstrate the engine operating at its rated power in a laboratory or on board of an actual vessel, thus going beyond the state of the art which is currently demonstrating ammonia combustion in smaller (road vehicle-based) test engines, or rapid compression machines.

Assuming feasibility, pathways toward deployment will be proposed.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-09-2022: Exploiting electrical energy storage systems and better optimising large battery electric power within fully battery electric and hybrid ships

Conditions related to this topic	
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 8 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and

	selection of a proposal requesting different amounts.

Expected Outcomes:

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked (“*”) whilst supporting the overall medium and longer term objectives:

- Contributions to two full scale vessel demonstrators, hybrid and fully electric, by 2027 covering a sailing distance of at least 300 nm in the case of a fully electric vessel.
- *Development and validation of electrical architectures for large battery systems on-board.
- *Proof of the safe integration of battery systems into the ship’s electrical grid for a relevant number of ship types (e.g. IWT, short sea vessels, cruise ships, ferries) and operational scenarios.
- *Verification of the architecture and the power management system for two cases: hybrid and fully electric.
- *Documentation of skills requirements for the crew.
- *In the short term, facilitate full battery electric transit for reduced noise and zero emissions on shorter routes (up to 100 nm) and during approach and harbour stay.

Scope:

Electrification and electrical energy storage is one of the major drivers for climate neutrality in the waterborne sector. 100% electrical power can potentially be used on any kind of vessel, with an initial focus on ferries and short sea shipping where re-charging can be frequent, but also extending within hybrid applications to larger vessels on longer routes as well as to high power vessels and high-end complex ships with a high number and a wide variety of electrical consumers.

Large battery based electrical energy storage systems offer the highest energy conversion efficiencies. Within fully electric ships, notably ferries, batteries are the most energy efficient method to achieve climate neutrality. Within ICE hybrid vessels batteries increase total efficiency, cutting engine peak power demands, providing a “spinning reserve” and enabling the possibility of zero emission port entries and coastal passages utilising only battery power.

The latest industrial outcomes in large marine batteries are already addressing safe, long-life and cost-effective solutions. On the other hand, at ship level, the development of systems which ensure the full integration of batteries in the ship’s highly complex electrical network is crucial to ensure the optimal use of the electrical energy stored, alone or in combination with other zero-emission ship power sources like, for instance, fuel cells.

Projects will develop solutions for the on-board integration (including the optimisation of the electrical distribution grid) and control of batteries which will maximise the operational flexibility of different ships under electric-driven zero-emission operations, focussing on an optimal operation and the longest lifetime and lowest weight of the electrical systems and its key components. While ensuring the ship's energy balance and efficiency, solutions need to address one of these two cases:

- The hybrid arrangement for zero local pollution (long and complete discharge cycles), or

- The full electric arrangement, plug-in charging (charging strategy and battery size adapted to route).

Strategies for safe energy management systems with sufficient safety margins need to be addressed.

Projects will also investigate (e.g. through performance modelling) different optimisation strategies for the large capacity batteries on board and will need to prove the applicability to several ship types and operational profiles. It will need to establish connections with the project(s) awarded under the Horizon 2020 call LC-BAT-11-2020 which is focused on the development of cost-efficient batteries, including the certification methodology.

Consideration should be given to technology transfer from potentially related sectors, such as the energy management from solar panel systems.

Long term skills' development needs and strategies with the aim to provide operational transferability of the developed solutions are integral to the topic and should also be investigated.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-10-2022: Innovative non-battery electric energy storage systems on-board vessels

Conditions related to this topic	
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Expected Outcomes:

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked ("*") whilst supporting the overall medium and longer term objectives:

- Contributions to at least two full scale on-board demonstrators for two different electrical energy storage solutions by 2027.
- Improve efficiency and make waterborne transport climate neutral through the exploitation of new innovative electrical storage systems.
- In the medium term, upscaling of proven solutions for a broad range of ship types (e.g. IWT, ferries, short sea shipping) and operational scenarios, as an alternative to batteries.
- Ensuring European leadership for energy storage solutions based on different technologies that will be fit-for-purpose for diverse waterborne applications.

- *Achieve a comprehensive understanding of potential innovative energy storage systems other than batteries and their applicability to waterborne transport.
- *Solutions to improve energy efficiency and make waterborne transport climate neutral founded upon innovative energy storage.
- *Comprehensive assessment of the technical feasibility and adequacy of innovative energy storage for a range of waterborne operations including efficiency, safety, cost competitiveness compared to batteries, skills requirements, and regulatory aspects.

Scope:

Battery based electric energy storage systems are increasingly deployed within the waterborne sector, particularly for sea short shipping, complex high-end ships and inland navigation.

Nonetheless, specific operational requirements (e.g. autonomy, power peaks, etc.), in particular in adverse conditions outside sheltered waters or going upstream on rivers, remain a concern. Fully battery electric shipping is demanding, requiring very high energy levels to achieve a realistic operational range and the necessary speed and thrust performance, whilst hybrid applications can also be excessively large. Both hybrid and full battery operations are subject to many more charging cycles and longer lifetimes than other transport applications.

Batteries within most waterborne applications deployments are founded upon established battery technologies. However, other energy storage systems exist which maybe valuable for waterborne application in the future which have not been fully investigated. For example, super-/ultra-capacitors, superconductivity magnetic energy storage, flywheels, flow batteries, etc.

Projects will focus on low TRL solutions for waterborne transport, preliminary integration, safety studies and the potential combination with other disruptive technologies such as super conductors and the wider use of DC grids. It will address the integration on-board of innovative energy storage systems (excluding storage of fuels and conventional batteries), including control systems and optimised operational deployment, and the connection to the on-board electrical grid.

Projects will address the cost competitiveness of the innovative solutions when compared with batteries, specify the applicability in specific waterborne segments (in particular in IWT where electrification may be pioneered through a dedicated project), determine risk levels, identify safety measures and propose possible regulatory aspects. The pertinent skills development will be outlined.

Activities will address innovative energy storage for waterborne applications, it will not address the internal design of the energy storage technology itself. For example, the design of super capacitors would be excluded.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-12-2022: Exploiting renewable energy for shipping, in particular focusing on the potential of wind energy

Conditions related to this topic	
Type of action	Research and Innovation Action

Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 9 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

<u>Expected Outcomes:</u>

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked ("*") whilst supporting the overall medium and longer term objectives:

- Renewable energy assistance is commercially viable and deployed at scale in commercial shipping and maritime operations, significantly contributing to making waterborne transport climate neutral.
- In the medium term, enabling the wide adoption of automated wind technologies for long distance maritime transport.
- *Through full scale demonstration prove the viability at large scale of power generation and propulsion assistance systems on-board harvesting renewable energies such as wind and solar.
- *System designs (including modular/drop-in) to reduce the costs of and increase confidence in refitting of the most appropriate existing vessels addressing several types of ships and different forms of renewable energy.
- *System designs including power management architectures and energy efficiency solutions (including wind-assisted and wind-based propulsion) for purpose built new ships including designs that are "wind-ready". Demonstration of efficiency gains of at least 15% for power generation or at least 25% for propulsion purposes.
- *Provision of a summary of pertinent regulatory issues and how to address them.
- *Documentation of skills requirements and incentives for the crew, for different types of ships and renewables adopted.

<u>Scope</u>:

The use of on-board renewable energies, in particular automated wind assistance, has potential to substantially reduce the ship's energy demands and hence reduce fuel consumption. Wind energy, harvested through e.g. rotors, hard and soft sails, kites, suction wings, turbines or specific hull forms, can serve multiple purposes on-board, including in particular primary propulsion with the additional beneficial effect of noise reduction. Potentially more expensive climate neutral fuels and carbon taxes will further enhance the economic benefits from efficiency gains and the exploitation of freely available renewable energies. With wind being a genuinely maritime feature shipping would also avoid costly competition with other transport sectors for sustainable fuels.

Whilst some renewable energy systems have been trialled at comparatively small scale, for particular routes and ship types, their scale has often been too small to provide conclusive data, and robust systems applicable for long distance trans-oceanic shipping are not yet available. R&I is needed to harvest the wind energy potential, significantly enlarging the current scale and expanding the typology for a much wider range of applications, demonstrating cost-effective, safe, reliable and easy-to-handle technologies in a variety of conditions. These conditions must be considered variable and dynamic if combined with beneficial changes in operational profiles such as advanced (satellite enabled) weather routing.

Overall energy efficiency strategies and architectures for the power management in large ships will be developed, with an optimised and self-adaptive operation of wind power systems as part of a hybrid architecture. For certain ship types and routes wind energy could become the main propulsion. This may in particular apply to smaller craft and fishing vessels (in transit) or to ships where wind propulsion can free bunker spaces for more paying cargo or passengers. In these cases attention must be given to the most practical and efficient system installation (e.g. retractable, auto-furling, hinged, multi-positional).

Projects will address both retrofitting existing ships and new purpose built designs, taking into account regulatory issues and making use of the existing guidelines by classification societies on wind-assisted shipping. Large scale testing and preferably demonstration is expected. Attention must be given to the conditions under which renewable power sources on-board compete with specific fuel solutions in terms of life cycle and opportunity costs, proven sustainability and reliable sourcing, and operational risks in order to make the most convincing business case.

In addition to wind, other renewables such as solar electric systems should be considered for different ship types, to the extent they can significantly contribute to the ship's overall power systems.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-14-2022: Transformation of the existing fleet towards greener operations through retrofitting

Conditions related to this topic	
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 5 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

<u>Expected Outcomes:</u>

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked ("*") whilst supporting the overall medium and longer term objectives:

- Accelerated achievement of climate neutrality of waterborne transport through retrofit modifications to the existing fleet.
- Ensuring cost effective solutions for retrofitting existing ships, thus supporting ship owners in the process of making the European fleet more environmentally friendly.

- Business models, industry standards, regulatory approvals, best practice guidance, and easy-to-customise strategies for retrofitting removing the commercial risk of deployment.
- Increased competitiveness of European shipyards, repair yards, and European marine equipment providers within the domain of green shipping technology.
- *Demonstrated retrofitting solutions for sea-going and inland navigation vessels in operation.
- *Retrofit solutions to reduce GHG emissions that are developed and ready to deploy. The target is to achieve a GHG emissions reduction of at least 35% compared to the original design.
- *Retrofit solutions involving climate neutral fuels making vessels GHG emission free. These solutions must have a significant R&I content going beyond a simple exchange of fuels through minor technical adaptations.
- *Establishment of an up-to-date catalogue of suitable solutions for a wide variety of ship types and operation scenarios.

Scope:

Progress towards climate neutrality of waterborne transport can be achieved more quickly by means of retrofit solutions that improve the performance of the existing fleet (sea-going and IWT) whilst solutions which are exclusive to new ships can only be implemented at the pace of the commercially driven fleet renewal.

In the trajectory towards the transition to new technologies that will make waterborne transport and operation greener and climate neutral picking the low hanging fruits is important. With the comparatively long life cycles of maritime assets and their high initial capital costs addressing the existing fleet is paramount in order to achieve fast and tangible results. Therefore, interventions that are easily implemented by shipyards, ship owners and operators need to be developed in the shortest possible time to reduce emissions from vessels already in service, both seagoing and those operating in inland navigation. The latter are particularly relevant as they tend to be in use in excess of 30 years and are largely owned by SMEs with limited investment potential.

In this context the owner-operator dilemma poses additional problem in the waterborne sector: A large number of ships are bareboat chartered by an operator who does not take investment decisions although he could benefit from them through lower running costs. The owner who would have to make those investment decisions, however, does not gain financial advantages as charter rates are generally fixed and depend on ship size and speed only. A performance related charter rate system has often been discussed but rarely implemented. Easy and relatively cheap retrofitting solutions may help in overcoming this dilemma.

For inland navigation and/or maritime shipping projects must address one or more of the following:

- Retrofit solutions to significantly reduce air or water pollution without increasing fuel consumption and hence GHG emissions, for example main engine abatement systems or engine and propulsion system modifications.
- Retrofit solutions which significant reduce GHG emissions through partial or full electrification, clearly progressing beyond the state of the art. Indicative examples are

battery ICE hybridisation for the main propulsion system and auxiliary power, electric network reconfiguration, electrical power management.

- Retrofit innovative hydrodynamic improvements (hull, hull management, appendages) to significantly improve energy efficiency and reduce GHG emissions by reducing fuel consumption.

Projects will focus on the design for technically and economically efficient retrofitting of the ship along these main lines. Cost efficiency of the proposed solutions will come from standardised and modular solutions applicable to different ships or by significantly reducing operational costs over the expected remaining life time of the asset. This may require new business models and implementation strategies based on a catalogue of solutions including smart maintenance. Attention will be paid to solutions which are not causing secondary emissions to air or water and which will not significantly increase fuel consumption.

This topic will contribute to the successful implementation of the ZEWT partnership.

C5-D5-WAT-15-2022: Seamless safe logistics through an autonomous waterborne freight feeder loop service

Conditions related to this topic	
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 15 million would allow these outcomes to be addressed appropriately in case of full demonstrations. For a limited demonstration and validation an EU contribution of EUR 7 million is considered appropriate. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

<u>Expected outcomes</u>:

Project outputs and results are expected to contribute concretely to the following expected outcomes as marked ("*") whilst supporting the overall medium and longer term objectives:

- Enable seamless safe logistics through an autonomous (or highly automated) waterborne freight feeder loop service for inland waterway and/or maritime transport applications. The autonomous system will provide an integrated, reliable, resilient, predicable fully automated service, also taking into account the interconnection of inland navigation and maritime transport in terms of serving the hinterland.

- Provide increased legal and regulatory certainty concerning autonomous waterborne services within national maritime and/or inland waters, e.g. concerning COLREGs, national and inter-governmental legislation etc. Expansion to the international dimension where feasible.

- Moving more freight by water with high levels of safety (taking in account all aspects related to fully autonomous navigation, e.g. manoeuvring, situational awareness, collision avoidance, failsafe operations), reduced environmental impact and contributions to climate neutrality, increased operational resilience and decongested land transport infrastructures.
- Autonomous waterborne freight feeder services can be taken up by the market on basis of a sound business case. Development of new business models based on autonomous waterborne feeder services within national maritime and/or inland waters.
- Reduced risk for first movers concerning autonomous waterborne technologies.
- Improved EU competitive advantage within global markets with respected to connected and autonomous shipping as well as broadening expertise across several member states.
- Exploitation of EU satellite navigation and other space based services.
- Better understanding of the societal issues and consequences of automated shipping services, in particular regarding skills challenges.
- *Preferably demonstrate the solution at full scale with all technology building blocks in a real world scenario. If full scale demonstration is unfeasible, solutions and key technology building blocks may be validated by means of testing within relevant environments, noting the lower project budget foreseen in this case.

Scope:

Digitisation and automation are increasingly disrupting business models and the operation of the waterborne transport sector.

Whilst digital and connected solutions are widely deployed, autonomous waterborne transport remains at an early stage of development, particularly outside of military applications. A small number of early stage demonstrators are foreseen in the coming years with modest ambition and focus. The main challenges are both technical and regulatory. Automated maritime or inland waterways feeder services are seen as the most promising applications where the feasibility and commercialisation of automated shipping can be proven. In particular, an autonomous waterborne feeder loop or shuttle service providing regular reliable, resilient and integrated supplies of freight with an ambition of zero emissions is likely to have many applications.

Developing the necessary expertise for such services provides Europe with a competitive advantage in the face of strong global competition which is investing to develop similar technologies. Autonomous waterborne feeder services are expected to disrupt logistics, remove freight from congested land infrastructures, increase safety by reducing the human factor in accidents and incidents, and make transport climate neutral. They will change business models, increasing logistic chain integration and exploiting telemetry and shore-based support, whilst modifying the role of crews and legal responsibilities which will raise further societal issues that need to be addressed. These anticipated changes to waterborne transport also require clarity concerning the local rules and regulations in order to ensure legal certainty. Project(s) must co-operate closely with the Horizon 2020 project MOSES which is already addressing aspects of robotic cargo handling and autonomous vessel maneuvering and docking.

Building on the current state of the art and on-going activities, proposals should address all of the following points in line with the expected outcomes above:

- Develop an autonomous waterborne freight feeder loop service for inland or maritime transport suitable for specific commercial applications and which can provide an integrated, reliable, resilient, predicable fully automated service with a preference for zero GHG and pollutant emissions as well as supporting safer navigation (e.g. manoeuvring, situational awareness, collision avoidance, failsafe operations). Feeder service is to be understood to include Ro-Ro services.
- Given that an IWT application will significantly differ from a short sea application common technology building blocks must be defined and developed. Project(s) must analyse differences and communalities in sufficient detail.
- Key aspects to be addressed are real time data acquisition, management, storage and exchange, and the supporting digital infrastructure(s), standards and connectivity, also addressing the potential use of Galileo GNSS services.
- Develop business cases which demonstrate the viability of the proposed solutions and their impact on logistic chains. The latter will require addressing port handling and intermodality.
- In addition to the vessel projects shoud address the port and any other necessary shore side infrastructure as well as any adaptions to existing infrastructure such as locks and bridges in the case of inland waterways transport.
- Address requirements for telemetry, its architecture, infrastructure monitoring and security needed for controlling the system’s water-side and shore-side assets.
- Address the necessary safety, regulatory and legal rules (including liability, COLREGs etc.) needed to deploy such services. A clear distinction must be made between inland navigation and short sea shipping as different legal, fiscal and commercial conditions as well as emission baselines apply. The possibility for modifications of COLREGS and similar regulations as well as a more active role of shore traffic management services should be explored.
- Whilst ensuring EU added value, and visibility of the EU’s activities, engage with wider activities addressing automated shipping, including internationally within IMO, as well as supporting EU policy making in the domain of autonomous and connected shipping.
- Address reliability, liability and the consequences of system failure or breakdown. Special attention must be given to cyber security and resilience against malicious acts in all aspects.
- Address the socio-economic implications of such automated feeder services, including employment, training and skills requirements as well as the social acceptance of such vessels. The latter may have higher pertinence where vessel operations are taking place in proximity to population areas.
- Broaden EU autonomous waterborne transport expertise amongst EU Member States.

C5-D5-WAT-16-2021: Computational tools for shipbuilding

Conditions related to this topic	
Type of action	Innovation Action

Technology or societal readiness level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 7 million would allow these outcomes to be addressed appropriately in case of full demonstrations. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Expected Outcomes:

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

- Achieve a competitive advantage for European shipbuilders within global markets, particularly for complex high added value vessels.
- Rapid early ship design (including an AI-based analysis of technical and legal requirements derived from historic data or from a structured feedback loop between builder and operator), underpinning the functional design concept and production cost estimations.
- Virtual prototyping to increase the reliability of early stage capital cost estimations, particularly taking into account the full range of greening options and innovative (and potentially difficult to cost) technologies such as green power systems (batteries, fuels etc.), the impacts on weight and revenue generating spaces as well as benefits towards operational cost.
- Provide benefits towards the competitiveness of the wider European shipbuilding sector, beyond single shipyards, through the creation of a fast, flexible and reliable design environment and platform that also includes repair yards. The platform shall be based on Industry 4.0 digital technologies and must be fully tested through a dedicated design case as a demonstrator. This shall include all relevant design disciplines and focus specifically on the full range of technologies supporting the reduction of emissions, with linkage to highly automated and robotised processes in parts manufacturing, assembly and outfitting with full supply chain integration.
- Integration of the ship design stages (conceptual, functional, production), considering also supply chain management issues. Demonstration of a future proof ship design concept based on modular architectures that allow for (cost) efficient retrofitting during the ship's life cycle.
- Computational shipbuilding tools and data management systems which are resilient to cyber threats.
- A European workforce that is highly skilled in the deployment and use of advanced computational tools in shipbuilding, particularly with respect to the integration of new technologies.

Scope:

Advanced computational systems are essential to Europe's competitive advantage in the construction, maintenance, conversion and repair of the world's most complex, high added value ships. Present computational systems are often proprietary, increasingly outdated and difficult to maintain whilst Europe's competitors are continuing to develop their advanced computational capacity. It is essential that Europe is able to maintain and extend its competitive lead within the high technology shipbuilding segment and that advanced computational tools are developed which in particular are able to integrate a wide range of emerging innovative technologies within designs, such as alternative power systems based on e.g. e-fuels, renewables, electrification, and hybridisation. Systems need to feed into competitive production processes as well as support potential changes to a ship design during its entire life-cycle.

The complexity of such tools and systems calls for novel solutions regarding design and production platforms, infrastructures, and services which may not be within reach of smaller European shipyards and design consultancies. Therefore, new concepts for a reliable and cost efficient roll-out of advanced platforms and tools must be developed and demonstrated.

Furthermore developments should benefit the wider European shipbuilding sector and address the necessary skills development to enable full exploitation of the advanced computation tools.

Proposals should develop advanced innovative computational tools for shipbuilding that increase the European sectors competitiveness by addressing all of the following points:

- Facilitate rapid early stage design to support lower risk bid development particularly when integrating innovative new technologies.
- Provide better capital cost estimations and performance predictions, particularly showing the improvements expected from the inclusion of new technologies.
- Tools to be integrated with ship construction and production, as well as considering supply chain management and future maintenance and repair of vessels.
- Address and quantify the competitiveness gains provided by the tool(s) in the context of the wider European shipbuilding sector.
- Ensure that the tool is robust and resilient against cyber threats.
- Identify and address the necessary skills development needed to achieve the maximum benefit from innovative advanced computational shipbuilding tools.
- Develop a business case to quantify the added value from the developed tool to the shipbuilder concerned and within the context of the wider European shipbuilding sector.

<u>Impact of transport on environment and human health</u>

Transport emissions are one of the main contributors to air quality problems, particularly in urban areas. At the same time, noise also negatively affects health. The World Health Organization (WHO) has classified traffic noise, including road, rail and air traffic, as the second most important cause of ill health in Western Europe, behind only air pollution caused by very fine particulate matter. Transport noise, particularly from road traffic, but also from rail and aviation, is a major contributor to noise pollution in urban areas. While type-approval noise limits for road vehicles, including their tyres, have been tightened over the years, the overall exposure to noise generated by road vehicles has not improved mainly due to increasing traffic volumes. L category vehicles are often perceived as a significant contributors to noise pollution and this might be due to the fact that noise emissions seem to be strictly optimised for specific conditions (but also due to tampering by their users, which in some cases is made too easy by the way the vehicles are built). Electrification promises to address most of these issues, but as some transport modes are more difficult to electrify in the near future, there is need for research and innovation activities to develop appropriate and environmentally sustainable solutions. Furthermore, possible new pollutants and related health- challenges need to be monitored and investigated, and ways to deal with emissions by the existing fleet need to be studied and demonstrated.

The main expected impacts are:

a) The reduction of road vehicle polluting emissions (looking at both regulated, unregulated and emerging ones) from both existing and future automotive fleets; prevention of smog episodes in Europe and a better understanding of the health impacts of air and noise pollution.

b) The monitoring of the environmental performance and the enforcement of regulation (detection of defeat devices, tampered anti-pollution systems, etc.) of fleets of transport vehicles, be it on road, airports and ports.

c) The reduction of noise emitted by L category road vehicles

d) Substantially reduce the overall environmental impact of transport (e.g.: biodiversity, noise, pollution and waste)

C5-D5-THE-01-2021: Development and demonstration of cost affordable and adaptable retrofit solutions for tailpipe and brake polluting emissions

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action (IA)
Technology or societal readiness level	Activities are expected to achieve TRL 8 by the end of the project – see General Annex D.

Expected Outcomes:

Project results are expected to contribute to [all/some] of the following expected outcomes:

- Cleaner urban air and water quality and reduced health impacts and damage to historic buildings due to lower emissions from road transport by 2025
- Affordable and adaptable retrofit solutions that with a fraction of the vehicle market value (e.g. 10% or less), could reduce the emissions of the existing Internal Combustion Engine (ICE) based fleet by over 50-60% for NOx and 90% for particles (exhaust emissions)
- Avoidance of transfer of pollution from high to low-income EU countries (exhaust emissions)
- Reduced health impact for highly exposed groups like public transport workers and users (emissions from brakes)
- Affordable and adaptable retrofit solutions to reduce particle emissions by over 90% for particles both in terms of numbers and mass (emissions from brakes)

- Reduced impact by heavy metals on soil and surface and ground waters (emissions from brakes)
- Reduced noise impact for retrofitted vehicles (exhaust emissions) and rolling stock (emissions from brakes)

Scope:

The impact of transport on air and water quality has been repeatedly found to be due to tailpipe emissions from older vehicles, vehicles exceeding emissions limits in real driving conditions, or by vehicles, which, by not being subjected to specific limits, have high emissions of certain pollutants (e.g. ammonia-fuelled vehicles which emit a high number of particulates). Considering that the current automobile fleet in Europe is unlikely to be significantly renewed within the next 10 years, the proposed research actions should address emissions of nanoparticles from indirect injection (i.e. conventional) gasoline and natural gas engines or Pre-Euro 6 c direct injection gasoline cars that will continue to occur for the next couple of years. In all these cases, when the vehicles are sufficiently recent and therefore not candidates for scrapping, the proposed actions on retrofit technologies should aim at reducing real emissions at a relatively low cost, thus providing an early improvement of air quality without waiting for the vehicles to be replaced (or exported to other markets, thus just shifting the pollution to poorer countries).

The Horizon Prize for the Cleanest Engine retrofit has already demonstrated very high NOx reduction performance on a high emitting Euro 5 diesel, and one of the participants has brought a product on the market, while at the moment no solution is present on the market for ammonia and particulates by vehicle categories not fitted with particle filters (natural gas cars, trucks and buses, gasoline cars). Therefore, the proposed actions should demonstrate in the field the results of deploying available retrofits, in particular to public and private fleets running high numbers of kilometres within the city (buses, delivery vans, taxis), as well as developing and demonstrating new, low cost retrofit technologies for natural gas buses and natural gas and gasoline cars in the above mentioned applications, with a clear validation in real driving of the reduction of emissions. The proposed actions should also consider awareness raising of little known emissions issues (for instance, ammonia and nanoparticles below the regulated threshold) and specific incentive schemes to facilitate the adoption of these technologies shall also be considered, taking into account the results of the currently running EU-funded projects on retrofits.

In addition to tailpipe particles, there is a growing awareness of the contribution by tires and brakes from road and rail vehicles. Brakes, different from tires, have the potential to emit large amounts of very fine particles and these can include harmful materials like heavy metals and resins. Moreover, they contribute to poor local air and water quality in specific and sometimes closed environments like bus stops, tunnels and train and metro stations. Therefore, the proposed activities should assess the specific contribution of brake particles on local air and water quality, possibly including citizen science contributions, for instance to assess the situation of complete network of metro and rail stations in cities or workers exposure, and to develop low cost retrofit solutions for these transport vehicles and demonstrate existing solution in the field to assess their benefit and usability/operating costs, while at the same time reducing the acquisition and installation costs, both for first installation and retrofitting (specifically on long-lived public transport assets).

In some specific cases, like urban heavy duty vehicles and rail rolling stock, noise is also an issue, therefore the retrofit solutions for these applications should also look at reducing exhaust noise, particularly during transients, while low particle emissions brake solutions should also look at integrating ways to reduce brake noise.

In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

Typically, projects should have a duration of 36 to 48 months. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts or durations.

C5-D5-THE-02-2021: Assessment of noise and particle emissions of L category vehicles from real driving conditions

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex D.

Expected Outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

- In-depth assessment of the noise and pollutant emissions of at least 150 L category vehicles, starting from the 10 top sellers of the different subcategories having significant sales (at least mopeds, 125cc, 250cc, 500 cc and above 500cc motorbikes, l6 and l7 microcars, light freight transport 3 and 4 wheelers), including different brands and geographical coverage. This will allow to take into account a large share of their environmental impact.
- Measures for mitigating the noise from L category vehicles
- Development of reliable detection techniques for tampered L category vehicles
- Best practices for integrating a growing number of L category vehicles in the urban traffic without increasing the noise and emission pollution

Scope:

Noise pollution is a growing environmental concern and has been affecting quality of life and well-being. It is caused by a varied number of sources and is widely present not only in the busiest urban environments, it is also pervading once natural environments. The adverse effects affect the well-being of exposed human populations, in the health and distribution of wildlife, in the abilities of our children to learn properly at school and in the high economic price society must pay because of noise pollution. Health effects, for instance, can be as bad as increasing the risk of hypertension and cardiovascular disease.

Whilst the increase in traffic volume results in higher noise levels, the increase in urbanisation results in a higher number of people affected by noise. As a result, the adverse health impacts, both direct and indirect, of traffic noise are expected to increase in the future despite potential noise-reducing improvements in vehicles, tyres and roads.

One of the ways of reducing noise from road (or rail) traffic is by tackling the problem at source. Setting lower emission limits via regulation is doubtless effective if it is based upon an appropriate test methodology, and good results have been achieved on large vehicles.

However L category vehicles are often perceived as a significant contributors to noise pollution and this might be due to the fact that noise emissions seem to be strictly optimised for specific conditions (but also due to tampering by their users, which in some cases is made too easy by the way the vehicles are built). Moreover, recent measurement campaigns in EU funded projects found some motorbikes having extremely high nanoparticles emissions. Real driving portable emissions measurement system (PEMS) tests will also allow to verify if there are issues in emissions testing, while lab tests shall assess the risks posed by particle emissions down to 2.5nm. Tampering is also often performed in order to increase performance, leading to higher emissions.

There proposals should address the following:

- assess the behaviour of a large sample of these L vehicles in real driving conditions for both noise and emissions in comparison with certification tests (complemented where necessary by lab tests, since mini-PEMS cannot measure certain pollutants like particles, ammonia and hydrocarbons)
- in particular, assess the real world driving behaviour that can produce particularly high annoyance and effect on health (noise emissions)
- propose specific technical improvements in the standard test procedure (performed in homologated test tracks) so that the tests could better approach real world driving conditions
- assess how significant the impact of these emissions is on urban environments and health and examine whether the current regulatory limits are sufficient
- assess how widespread tampering is, its impact on global urban noise and emissions lev, its impact on global urban noise and emissions levels, and propose solutions to prevent it
- develop reliable technological solutions and effective experimental techniques for better enforcement of the regulatory measures for detecting noise under real driving conditions

This action will be focussed in particular in cities and regions with high powered two wheelers use and the derived knowledge will provide significant support to designing future measures aimed at reducing the noise and pollution emission levels from these vehicles.

Projects should make use of available results and technologies from projects funded in projects on remote monitoring issuing from topics LC-MG-1-1-2018 and LC-MG-1-9-2019, and from projects on nanoparticles measurement issuing from topic GV-02-2016.

In line with the Union’s strategy for international cooperation in research and innovation, international cooperation is encouraged.

C5-D5-THE-03-2022: Prevent smog episodes in Europe: Air quality impact of engine-emitted volatile and semi volatile as well as secondary particles

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 2.5 and 3 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

Expected outcomes

Project results are expected to contribute to [all/some] of the following expected outcomes

- Achieve better understanding of (semi)volatiles particles and secondary aerosol formation as well as their effects on health, air quality (in particular during winter season) and climate
- Assess the contribution to PM2.5 of precursors present in exhaust from transport (i.e. volatile organic compounds, NOx, unburned hydrocarbons, nano-particles below 23nm, ammonia, etc.) through the formation of secondary aerosol (organic –SOA- and inorganic)
- Find ways in which scientific evidences of the role of emissions in atmospheric processes could be an input to develop policies and mitigate SOA formation in urban areas of EU.
- Improved quantification of transport externalities
- Support of future emissions legislation and of “polluter pays” legislation

Scope:

The impact of transport emissions on air quality and health is relatively well known as far as direct pollutants emission are concerned, i.e. particulate, NOx, hydrocarbons etc. However, some of the emissions from engines and combustion processes in general are also leading to further formation of health impacting compounds due to atmospheric aerosol chemistry, and the specific impact of these compounds is less understood (except for ozone, whose chemistry has been widely studied for other reasons). Also, in fields where regulation limits particles emissions (cars, trucks, aircraft, non-road mobile machinery) current engine particles emissions count only assesses the number of solid particles, disregarding the so-called volatile and semi-volatile particles, thus underestimating the impact on air quality and health.

Proposals should assess in detail engines emissions in Real Driving Emissions (RDE)-compliant testing conditions (based on currently used fuels) leading to volatile and semi-volatile and secondary particulate, taking into account the wide available literature and results from projects issuing from topics LC-MG-1-1-2018 and GV-02-2016, prioritise them according to available information and assess their health impact with relevant modelling and in vitro and in vivo testing.

After assessing the risks associated to each emission, proposals should define a robust and transparent measurement and modelling system in order to determine an equivalent total particles emissions index for each engine encompassing all these emissions, to complement the direct solid particles emissions count currently in use to better quantify the total externalities of combustion engines in all transport fields and related fuels.

In line with the Union’s strategy for international cooperation in research and innovation, international cooperation is encouraged.

Destination 6 – 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.

Expected impacts at Destination-level and their link to expected impacts of the Strategic Plan

Activities under this Destination should set out a credible pathway for contributing to the following **Destination-level expected impacts** (more detailed impacts for each thematic area are elaborated in the introductory text of the thematic area):

a) Drastically decrease 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).Increase the resilience of transport systems.

b) Accelerate the implementation of innovative connected, cooperative and automated mobility (CCAM) technologies and systems for passengers and goods.

c) Further develop 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.

These Destination-level impacts will directly support the **Strategic Plan's expected impact** of *"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"*.

Connected, Cooperative and Automated Mobility (CCAM)

The aim is to accelerate the implementation of innovative connected, cooperative and automated mobility (CCAM) technologies and systems. Actions will help to develop new mobility concepts for passengers and goods – enabled by CCAM - leading to healthier, safer, more accessible, sustainable, cost-effective and demand-responsive transport everywhere.

CCAM solutions shall foster and support new mobility concepts, shifting design and development from a driver-centred to mobility-user oriented approach, providing viable alternatives for private vehicle ownership while increasing inclusiveness of mobility. CCAM must be integrated in the whole transport system to fully exploit the potential benefits of CCAM and minimise potential adverse effects, such as increasingly congested traffic or new risks in mixed traffic environments.

The focus is on road transport, but relevant interfaces with other modes (for instance transfers and integration with public transport or rail freight transport) will be considered.

Actions will include large-scale demonstrations to test the performance and safety of innovative shared automated mobility solutions and to study the socio-economic and environmental impacts, including possible rebound effects, and the acceptance of these solutions by users and society. The development and demonstration of innovative technologies for connected and automated vehicles and infrastructure, connectivity and cooperative information supporting CCAM the validation of all aspects of the CCAM system as well as the integration of CCAM in the overall transport system will also be addressed. Another priority will be to support actions for the coordination and cooperation of R&I and testing activities across Europe.

All technologies, solutions, testing and demonstration activities resulting from these actions should be documented fully and transparently, to ensure replicability, increase adoption, up-scaling, assist future planning decisions and EU and national policy-making and increase citizen buy-in.

Actions are in line with the recommendations of the new European Partnership on CCAM. This partnership aims to harmonise European R&I efforts to accelerate the implementation of innovative CCAM technologies and services. It aims to exploit the full systemic benefits of new mobility solutions enabled by CCAM: increased safety, reduced environmental impacts, and inclusiveness. By bringing together the actors of the complex cross-sectoral value chain, the Partnership will work on a shared, coherent and long-term R&I agenda. The Vision of the Partnership is: “European leadership in safe and sustainable road transport through automation”. The European Partnership on CCAM plans to closely cooperate with other European Partnerships, in particular with “Towards zero emission road transport” (2ZERO), “Driving Urban Transitions” (DUT), “Key digital technologies” (KDT), “Smart networks and services” (SNS) and “AI, data and robotics” (AI). The European Partnership will establish cooperation mechanisms to ensure close interaction when defining R&I actions to maximise synergies and avoid overlaps.

Proposed actions should explore the potential for international cooperation to facilitate technology development and market uptake of CCAM solutions.

R&I actions taking place at a socio-technical level aiming to better understand the science-society relationship (particularly when social practices, market uptake or ownership are concerned) should favour solutions that are grounded in social innovation in order to achieve its desired outcomes, i.e. by matching innovative ideas with social needs and by forming new collaborations between public and private actors, including civil society.

To test CCAM solutions, applicants can seek possibilities of involving the European Commission’s Joint Research Centre (JRC) in order to valorise the relevant expertise and physical facilities of JRC in demonstrating and testing energy and mobility applications of the JRC Living Lab for Future Urban Ecosystems[76].

The **main expected impacts** are:

[76] https://ec.europa.eu/jrc/en/research-facility/living-labs-at-the-jrc

- Validated safety and security, improved robustness and resilience of CCAM technologies and systems;
- 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;
- High public acceptance and adoption of CCAM with clear understanding of its benefits and limits as well as rebound effects; based on the changing mobility needs and desires of a society in transition (digitally and environmentally);
- Better coordination of R&I and large-scale testing activities in Europe and expanded knowledge base on CCAM solutions

The following topics are being considered by the co-programmed European Partnership on CCAM for further development:

C5-D6-CCAM-01-2022: European demonstrators for integrated shared automated mobility solutions for people and goods

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 20 and 23 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action (IA)
Technology or societal readiness level	Activities are expected to achieve TRL 7 by the end of the project – see General Annex D.

Expected outcomes:

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

- Demonstration of inclusive, user-oriented and well-integrated shared CCAM systems and services for people and goods in real traffic conditions, which contribute to
  - reduced carbon footprint and harmful emissions
  - reduced congestion, more reliable, predictive travel times and more efficient transport operations
  - increased safety and security.
  - End-users’ adoption for specific use cases of innovative shared mobility solutions.
- Demonstration of innovative cross-sector business models and partnerships for CCAM
- Assessment of all impacts of shared CCAM solutions in real world conditions, specifically on sustainability, inclusiveness and safety based on viable economic use cases for passengers and goods.

Scope:

CCAM solutions shall provide a more user-centred, all-inclusive road mobility, while increasing safety, reducing congestion, emissions and contributing to climate neutrality. These novel mobility services enable seamless integration with existing services (e.g. public transport, logistics), and higher levels of automation support, transport productivity and efficiency (e.g. transportation of goods at lower speeds to save energy, operational efficiency at logistics hubs and in hub to hub corridors or last mile operations). Yet all these benefits need to be proven. Previous and currently ongoing demonstration projects for CCAM systems and services show, that further testing of highly automated systems and services with high scaling potential is necessary, involving more mature technologies or additional use cases in extended Operational Design Domains (ODDs). Proposed actions for this topic must address all the following aspects:

- implement a set of European demonstrators of smart, shared mobility and/or logistics use cases in real traffic conditions with ambitious and realistic operational domains (balancing environmental complexity, risk, speed, economic viability, etc.) enabled by CCAM solutions (SAE Level 4) with market potential (i.e. with scalable business and operating models).
- test robustness, reliability and safety of highly automated CCAM systems and services, while focussing on user interaction and interaction with other road users (specifically vulnerable road users such as pedestrians and cyclists). This includes testing of key enabling technologies (e.g. sensors, connectivity, cybersecurity, AI, big data, space-based services), physical/digital infrastructure support and optimised traffic and fleet management.
- address user and customer needs for mobility and logistics. Further, deploy high quality services that are well integrated with other modes and existing mobility services,
- apply, test and demonstrate the common evaluation framework for large-scale demonstration pilots in Europe and the test data exchange framework, provide input to the EU-wide knowledge base on CCAM (see topic C5-D6-CCAM-11-2021) and contribute to the EU wide database of relevant scenarios (see topic C5-D6-CCAM-04-2021).

Proposed actions should contribute to effective assessment and demonstration of benefits on energy efficiency, traffic flow, safety, user appreciation, etc. based on holistic modelling solutions. If possible, already existing investments at national and European level on demonstration activities should be leveraged, optimising return on investments and create a strong basis for even larger scale demonstrations and system integration.

Proposed actions should foster the collaboration between public and private stakeholders (e.g. cities, regions and infrastructure operators, authorities, civil society organisations, public transport operators, OEMs and suppliers, logistics hubs, freight transport and logistics service providers and freight transport and logistics users, research providers, ITS and telecom sector) to achieve common objectives and assess societal impacts. Co-creation with users should be considered to demonstrate benefits and raise public acceptance/adoption of CCAM under real-world conditions.

Proposed actions have to focus on demonstrators for integrated shared automated mobility solutions for people, for goods or for both, and should address resulting synergies and complementarities in the CCAM ecosystem when possible. All vehicles used for testing the innovative CCAM concepts should use zero emission technologies.

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

C5-D6-CCAM-02-2021: More powerful and reliable on-board perception and decision-making technologies addressing complex environmental conditions

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 6 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action (IA)
Technology or societal readiness level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex D.

<u>Expected outcomes:</u>

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

- Determination of the appropriate compositions of cost-efficient sensor suites that most effectively and reliably deliver the lateral, spatial and temporal resolution needed for real-time driving decision-making of Connected and Automated Vehicles (CAVs).
- Ability to perform advanced environment and traffic recognition and prediction, limiting false detections and non-detections of obstacles, with particular attention to Vulnerable Road Users (VRU), in order to reduce existing disparities in the harm-to-exposure ratios of these vulnerable groups.
- Ability to determine the appropriate course of action of a CAV in a real world environment with a wide range of traffic scenarios and identify use cases in which the vehicle’s decision-making might be contradictory to existing traffic rules (e.g. to make way for a priority vehicle, to obey police officers directing traffic).
- Availability of robust, transparent and accurate systems to enable the safe and reliable operation of automated vehicles in expanding Operational Design Domains (ODDs) including all weather conditions, complex urban environments, challenges in rural environments, etc.
- Standardization mandate for performance requirements for environment perception systems with respect to different automation levels and ODDs

<u>Scope:</u>

To achieve secure and trustworthy interaction between vehicles, infrastructure and road users, robust (e.g. weather resilient) and accurate on-board environment positioning and perception systems are essential for the extraction of reliable information required for real-time driving decision-making. Furthermore, advanced on-board decision-making functionalities must handle the diversity of use cases in their respective operational domains. Such functionalities have to guarantee the safety and reliability of future automated vehicles, which will integrate complex in-vehicle systems-of-systems with advanced sensors, control and actuators, relying on extensive computational power and an increased dependency on software for decision-making.

The proposed actions must address the development and demonstration of each of the following aspects:

- More powerful and reliable embedded in-vehicle perception systems with increased performance, (weather) resilience and accuracy based on enhanced sensing, localization (with reliable, dynamic, high-definition digital maps, reliable and precise location from EU satellite navigation services) and improved object/person classification and cognition (with greater integration with infrastructure-based perception systems and other vehicles to complete data fusion and real time updates). Projects involving satellite-based earth observation, positioning, navigation or timing data, services or technologies must make use of Copernicus and/or Galileo/EGNOS data, services and technologies. Other programmes or systems may additionally be used.
- System self-assessment methods for environment perception technologies and improved hardware integration into the vehicle need also to avoid reliability issues due to environmental stresses, temperature shifts, vibrations, potential malicious attacks, low speed crashes, etc.
- On-board, real-time, fail-safe, unambiguous and traceable decision-making systems for safe Connected and Automated Vehicles (CAVs) based on complex in-vehicle systems-of-systems requiring extensive computational power and highly advanced algorithms in order to address complex traffic scenarios (with VRU). These systems should be cost effective and respecting the protection of personal data with improved minimum risk manoeuvres in the event that the limit of the ODD is reached or in the case of a malfunction.

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

C5-D6-CCAM-03-2022: Reliable occupant protection technologies and HMI solutions to ensure the safety of highly automated vehicles

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 6 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

<u>Expected outcomes:</u>

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

- Protection systems in Connected and Automated Vehicles (CAVs) designed for a greater variation of unconventional seating positions and body postures, to be sufficiently inclusive to encompass the diversity of the occupant population, considering all situations and conditions for the application of such systems and taking into account different accident configurations with a higher market penetration of CAVs.

- New, advanced Human-Machine-Interface (HMI) solutions as enablers for the safe and efficient co-existence and interaction of CAVs with other road users (including Vulnerable Road Users and non-automated vehicles). Interfaces must be reliable and seamless, based on comprehensive knowledge and models of individual human behaviour and capabilities.
- Advanced driver/passenger condition monitoring and improved HMI functionalities to prepare the driver to take control as may be necessary when the vehicle reaches the limits of its Operational Design Domains (ODD).
- Consistent design methodologies and tools for performance assessment of the new protection systems.
- Delivering evidence-based support to the regulatory bodies for the potential adaptation of traffic rules.

<u>Scope:</u>

In order to ensure the safety of highly automated vehicles, on-board systems need to anticipate risks reliably, prevent crashes and minimise the consequence of unavoidable collisions while enhancing user acceptance, and generating trust and reliance on automated systems through well-designed, informative Human-Machine-Interfaces.

The proposed actions should address all the following aspects:

- Development of vehicle crashworthiness and advanced safety solutions in order to protect passengers and mitigate injury risk in unavoidable collisions also with new, unconventional seating positions and body postures, considering new protection principles and taking into account all situations and conditions for the application of such systems (for example in shared automated road vehicles). This also includes the identification of new accident configurations and adaptations to the structural layout of vehicles.
- Development of empathic HMI solutions, which includes a framework for modelling human emotions, in order to enable natural and intuitive interaction of CAVs with the driver, passengers and with other road users (including unprotected ones) also in mixed traffic situations.
- Monitoring approaches and simulation models to detect and assess occupant status (including health) and level and point of attention of the driver, enabling appropriate HMI, linked also to the new intelligent protection systems in order to fully leverage their potential in terms of adapting to different seating positions, body postures, occupant sizes etc.
- Improved solutions to address situations in which human drivers shall seamlessly resume control, for example when the limit of the ODD is approaching.
- Recommendations for user-centric HMI design guidelines and for an extension of the European Statement of Principles for human-machine interaction (ESoP)77 towards

[77] European Commission Recommendation on safe and efficient in-vehicle information and communication systems: update of the European Statement of Principles on human-machine interface, 2008/653/EC

automated vehicles should be derived, taking into account also the interaction with unprotected road users and other non-automated, non-connected vehicles.

- Development of assessment tools for the developed protection technologies and advanced safety solutions in order to support the definition of safety requirements, standards (e.g. UNECE) and the analysis of potential needs for the adaptation of traffic rules.

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

C5-D6-CCAM-04-2021: Common approaches for the safety validation of CCAM systems

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 12 and 15 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

Expected outcomes:

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

- Common methodologies and tools for the safety validation of CCAM systems defined, accepted and validated
  - by the CCAM value chain and its R&I partners for the efficient verification of CCAM systems in their R&I and product development processes,
  - by authorities and certification bodies for the validation of CCAM systems within type approval schemes and in future exemption procedures,
  - and by consumer testing campaigns for the safety rating of automated vehicles assisting users in identifying the safest choices for their needs.
- Verification, validation and rating procedures based on realistic and relevant test cases generated from an openly accessible EU wide database, compliant with the FAIR data principles78, providing the widest possible range of relevant scenarios, which CCAM systems will potentially encounter on EU roads as a basis for robust system design.

Scope:

[78] Final Report and Action Plan from the European Commission Expert Group on FAIR Data, "TURNING FAIR INTO REALITY" - https://ec.europa.eu/info/sites/info/files/turning_fair_into_reality_0.pdf

A decisive factor for the successful implementation of innovative CCAM technologies and for their acceptance and adoption in society will be assuring the effective safety of CCAM systems.

While different assessment methods for automated driving functions have been developed, common standard methodologies meeting all the requirements for testing, validation and certification of all levels and use cases of automated driving do not yet exist. Therefore, consensus building between all stakeholders is urgently needed to establish common, validated methodologies and tools. Existing approaches are currently analysed in Horizon 2020, an experts' network has been set up and validation concepts are demonstrated for selected use cases e.g. in the HEADSTART project[79].

Proposed actions should move the development of common verification and validation methodologies to a new level by widening substantially the scope of use cases addressed and by preparing the required tools to enable the comprehensive safety verification and validation of CCAM systems. This must take into account mixed traffic situations and include functional safety issues and cybersecurity. Such methodologies and tools should allow for their further development and adaptation with future technological evolution. Scenario-based approaches combining virtual and physical testing are needed, as conventional verification and validation approaches would require hundreds of millions of test kilometres for higher levels of CCAM.

Proposed actions must develop a commonly accepted and harmonised simulation environment with standardised, open interfaces and quality controlled data exchange to enable the virtual testing of CCAM functions and systems in a multitude of relevant test cases and to enable the efficient and seamless use of validated models from different sources.

The validation of CCAM systems depends on the definition of relevant safety-critical scenarios and test cases. Several national and European projects have started to collect such scenarios and store them in databases. There is, however, no EU wide database of relevant scenarios nor an agreed database structure. Scenario descriptions also need to be harmonised and not all relevant scenarios are known. Therefore, proposals must define and develop processes and tools to continuously identify relevant events and convert them into detailed scenarios from various sources (including accidents), complemented by an ontology-based tool to define relevant future/theoretical scenarios. Diverse weather, lighting and road conditions, a broad spectrum of behaviour of other road users as well as edge cases should be considered. Following the collection of such scenarios, which can partly be derived from other projects and collaborations, scenarios need to be shared and centrally stored in an EU wide database. This database must be established by the proposed actions based on an agreed structure and a harmonised scenario description (ontology layer) and metadata framework, in line with the FAIR data principles.

Proposed actions must develop recommendations for harmonisation, standardisation and homologation including the conceptual description of an approval scheme for CCAM systems considering all types of vehicles and fed into on-going discussions regarding EU type vehicle approval rules as well as in the framework of the UNECE.

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

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[79] https://www.headstart-project.eu/

C5-D6-CCAM-05-2022: Human behavioural model to assess the performance of CCAM solutions compared to human driven vehicles

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 4 by the end of the project – see General Annex D.

Expected outcomes:

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

A robust and scalable reference model of human driving behaviour:

- Replicating the full performance spectrum of human drivers, which allows comparing the performance of an automated driving system in a specific situation to the human driver population. This serves as a basis to define the required safety level of CCAM systems and to take decisions on validation requirements in type approval schemes. The model will also help to define fair assessment criteria in consumer testing campaigns relative to human-driven vehicles and for the safety verification of CCAM systems in industrial development processes.
- Serving as a reference for the automotive industry and its R&I partners to design human-like and therefore easily predictable and acceptable behaviour of automated driving functions in mixed traffic.
- Helping the automotive industry, its R&I partners, certification bodies and consumer testing organisations to realistically represent the behaviour of other human-driven vehicles in the (virtual) simulation of mixed traffic. Virtual testing shortens development cycles and accelerates the implementation of CCAM technologies.

Scope:

Statistical data available today gives a good idea of overall human driving, vehicle and infrastructure performance in terms of safety. However, evidence is missing on the precise performance of humans in the variety of specific situations that might be critical for automated driving systems. The variability of human behaviour and performance with factors like gender, cultural and ethnic background, ageing, diseases, driving experience, mental workload or fatigue makes the acquisition of such evidence a very challenging task. External factors such as diverse weather and lighting conditions play a role in this context, as well. Data on the dependence of human driving behaviour from such factors is partly available from previous research, but not sufficiently broken down to the level of specific driving situations.

Available software modules to simulate human driving behaviour only cover specific aspects of human driving performance so far and do not cover the full spectrum of drivers with statistical data on the probability of certain behavioural patterns.

Therefore, proposed actions have to develop a probabilistic human behavioural model with the potential to cover all relevant aspects of human driving performance as well as the broad spectrum of drivers and influencing factors. A methodology will be needed to extract consistent data on human driving performance from different data sources (e.g. real traffic, simulator tests) and collect such data with the long-term objective of fully depicting the large variance of human driving behaviour in different situations, while respecting gender, age and other factors like disabilities and diversity criteria. Proposals should calibrate the parameters of the model with the help of this data, and develop a corresponding validation concept based on real-world experiments. Potential ethical issues will have to be considered, as tests with humans need to be carried out and their personal data will have to be captured. The model should be transparent, independent from proprietary software tools and easy to use. It should be validated at least for selected fields of application with the perspective of extending these fields of application gradually and also simulating human behaviour in future scenarios of mixed traffic.

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

C5-D6-CCAM-06-2021: Physical and Digital Infrastructure (PDI), connectivity and cooperation enabling and supporting CCAM

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 7 and 9 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action (IA)
Technology or societal readiness level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex D.

Expected outcomes:

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

For Area A:

- Common understanding of requirements and minimum set of infrastructure adaptations for the physical and digital infrastructure for CCAM systems and services, in mixed traffic with conventional vehicles and other road users and modes of transport.
- Description and development of service architectures of PDI for CCAM systems and services and agreed classification of infrastructure support levels stimulating EU-wide/global harmonisation for classification of infrastructure support.
- PDI support concepts of proven maturity (technically, functionally, etc.), developed in cooperation with road users and vehicle manufacturers to extend their Operational Design Domains (ODD), and ready for large-scale demonstration actions.

For Area B:

- Connectivity and cooperation enablers and needs for higher levels of automation identified and assessed, based on a detailed use-case-approach for the CCAM mobility system.
- Requirements for availability (e.g. coverage, security) and performance of connectivity and cooperation enablers (e.g. data rates, latency, robustness and redundancy, quality of service, resilience against cyberattacks) specified per use case, meeting requirements of functional safety and safety-critical applications,
- Ensured quality of and trust in external data by common definitions (incl. quality indicators definition) meeting requirements of cross-border interoperability and continuity,
- Feasible and sustainable concepts for and provision of road infrastructure coverage (short- and long-range connectivity along the road network) developed to enable CCAM services, included in testing at living labs and ready for large scale demonstration

Scope:

Physical and Digital Infrastructure (PDI), connectivity as well as cooperative information and action represent important resources which enable and support the integration of vehicles in the entire transport system. Road authorities and operators can provide essential PDI information to vehicles, road users and other modes of transport. As a complement, connectivity and cooperation are important capabilities of the full range of V2X actors (vehicles, infrastructures, vulnerable road users etc.). This is a necessary condition to proceed towards CCAM services in a developing CCAM ecosystem (involving benefits for e.g. road and mobility users, manufacturers across sectors, traffic management actors).

Actions must address the activities either under area A) Physical and Digital Infrastructure (PDI) supporting CCAM or under area B) Connectivity and cooperation as enablers for CCAM and advanced traffic management while taking into account the complementing nature of both areas.

Area A: Physical and Digital Infrastructure (PDI) supporting CCAM

The Physical and Digital Infrastructure (PDI) is pivotal to improve CCAM services. The physical elements of infrastructure include markings, road signs, layout, etc., while the digital components encompass digitised spatial network including relevant traffic rules and regulations, input from road-side sensors, HD maps integrating static and dynamic data, etc. PDI support will particularly help in more challenging geographical or weather conditions, and can mitigate failure situations or gaps in the Operational Design Domain (ODD).

Research results so far have shown that the definition of ODD and infrastructure support level requirements serve as common basis of physical and digital infrastructure attributes in different Operational Environments (e.g. highly complex urban, interurban and motorway, peri-urban, dense traffic). Proposals must develop a service architecture built upon this basis, which improves the functionality of highly automated vehicles by supporting their "sense, plan and act" ability. This service architecture will provide PDI support, which offers a finer gradation of dynamic traffic management regulations and can further increase the functional safety and the traffic efficiency – or more general, the performance – of CCAM services. Secure and trustworthy interaction between vehicles, infrastructure, and third-party services must be ensured, as well as addressing the aspect of maintenance/evolution for both types of infrastructure.

Proposed actions should build upon recent work of the CCAM Platform on classifying PDI elements[80] and develop a comprehensive classification scheme that also allows for describing the PDI support (and the regular update) on road network sections (what, where, when).

R&I actions should advance the technological readiness of PDI support (e.g. Proof-of-Concept) to level 6/7 on the way towards (pre-) deployment as an important contribution to large-scale demonstration actions.

Recurring technology and process innovation however bears the risk that investment, especially in sectors with long cycles, are devalued well before their (end of) lifetime. It is crucial to balance premature action versus deferral of decision making and proposed actions should therefore analyse the risks, benefits and required investments in PDI support and provide guidance towards minimum adaptations of PDI that provide a substantial and sustainable added value to CCAM.

Proposals should take into account that 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.

Area B: Connectivity and cooperation as enablers for CCAM and advanced traffic management

CCAM systems and services as well as advanced traffic management use connectivity and cooperation for e.g. exchanging information on status and intentions, realising collective perception, planning cooperative manoeuvres on roads, negotiating slots (time, space) for executing manoeuvres. The first generation of C-ITS services (Day 1 services), limited to provide status information, represents a prominent example of grown technological readiness that have recently made their way into deployment in vehicles and the road infrastructure. The next wave of services, also taking advantage of emerging technologies, should enable connected cooperative automated mobility. Proposals have to build upon or further progress already deployed services, first concepts and message designs for next generation C-ITS services, as developed in C-ROADS, as well as insight from ongoing 5G Corridors for Connected and Automated Mobility. Proposed actions should address and sufficiently test all the following aspects in real traffic conditions:

- Data provision through communication channels from external sources (e.g. road status, traffic and weather conditions from vehicle external sources) increasing the functionality of CCAM services and traffic management as well as road safety, traffic efficiency and environmental protection.
- Ensuring interoperability and continuity of services, backwards compatibility of proposed solutions, supporting a mixed use or range of technologies (hybrid

[80] To gain a deeper understanding how infrastructure can support CCAM, CCAM Platform WG 3 (Physical and Digital Road Infrastructure) is working on a matrix linking physical and digital infrastructure attributes to basic driving tasks of sense – plan – act. Moreover, the WG 3 scoping paper provides recommendations for follow-up actions addressed to the CCAM partnership, a.o. to identify pre-deployment opportunities. More information on Working Group 3 of the CCAM Platform:
https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3657

communication) while ensuring privacy and security for all, in all communication channels.

Because of the enabling nature of connectivity and cooperation as well as cross-sector links, proposed research has to contribute to an integrated collaborative perspective of CCAM. Proposals should include in research and testing all relevant actors across sectors to co-design CCAM services. Proposals should also embrace the necessity to come up with concepts for a sustainable organisation of the necessary co-investment, co-management and joint implementation of CCAM.

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

C5-D6-CCAM-07-2022: Integrate CCAM services in fleet and traffic management systems

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (IA)
Technology or societal readiness level	Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex D.

<u>Expected outcomes:</u>

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

- Concepts of fleet and traffic management in the CCAM eco-system enabling optimised systems for the mobility of people and goods that take into account the balance between societal and individual user needs.
- Intermodal interfaces and interoperability between traffic management systems (of different geographical locations and/or of CCAM vehicles and other modes of transport) considering integration beyond road transport in the overall multimodal transport system providing seamless mobility services.
- Advanced simulation models and tools that enable and help assessing new traffic management strategies (including dedicated lanes, priorities at intersections etc.) for CCAM.
- Optimised mobility network load balancing approaches through advanced traffic management guidance and information loops that can reach individual users as well as operational traffic management actors.
- Effective cooperation and governance models for operating CCAM services as part of real-life fleet and traffic management systems developed and tested.

<u>Scope:</u>

Proposed actions should develop and demonstrate concepts of traffic and fleet management to achieve a desirable integration of CCAM vehicles in the entire mobility system. CCAM vehicles should be considered in their different sizes and usages as well as their mobility service provision (private, public, shared, pooled etc.). Proposed actions should address both the transport of people and goods with automated fleets (commercial/logistics fleets, fleets operated by public or private transport operators) and individual vehicles (CCAM- or conventional vehicles) well integrated in the entire traffic management system. They have to address technology gaps to foster vehicle integration, communication and better manoeuvre coordination and orchestration concepts in managing fleets and traffic as well as integrating public transport and other shared mobility concepts. This involves planning, forecasting and managing fleet and individual vehicles' movements according to their specific needs. Proposed actions should demonstrate traffic efficiency improvements by mobility network load balancing of routes, optimizing reliability of arrival times of goods delivery or shared mobility services, organize measures in case of events, or bilateral communication and acknowledgement of traffic management guidance if advised from an appropriate control centre.

Proposed R&I actions must address intermodal interfaces and interoperability between traffic management systems from one geographical location to another and from one user group to another to attain seamless mobility for all.

Proposed actions should develop and demonstrate mixed traffic orchestration concepts, enabling or involving new mobility business cases for fleet operation (logistics, public or private transport operator, etc.). These new fleet and traffic management approaches must closely link to societal and individual user needs (including VRUs and other connected or non-connected users).

Advanced simulation models and tools shall be able to test and demonstrate in real life traffic their ability to support the optimisation and balancing of the mobility network load. Testing and demos in real life traffic conditions should be undertaken through engagement with stakeholders from the industry, public authorities, public and private operators, service providers, the research sector and road and vehicle users and by satisfactorily addressing the priorities of all (win-win-win).

Governance of the traffic management system has to take into account the needs and requirements of the users and the availability of services enabled by CCAM and the accordingly relevant supporting infrastructure. Both citizen-led needs and CCAM developments will guide the governance of traffic management systems which will eventually see the CCAM fleets of private and public transport (including on demand PT) integrated fully into the transport network.

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

C5-D6-CCAM-08-2021: Cyber secure and resilient CCAM

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 5 and 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or	Activities are expected to achieve TRL 5 by the end of the project – see

societal readiness level	General Annex D.

Expected outcomes:

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

- Safe and secure operation of CCAM vehicles and mobility systems and services, enhancing trust and end user adoption of CCAM solutions.
- Cybersecurity requirements including data security and access control enabling harmonised approaches and tools for data sharing.
- Improved understanding of the new, emerging and specific CCAM related cyber security and resilience challenges, by using the contextual definition, including sector specific security features.
- Inclusion of cybersecurity and resilience as an integral part into the development process of CCAM solutions by OEMs, Tiers, telecom providers and service providers, with common aims and objectives, frameworks/architectures and designs
- Cybersecure data sharing approaches from pilot applications towards CCAM on a harmonised larger scale.

Scope:

Safe and secure operation of vehicles and mobility systems is key to the further deployment of CCAM enabled mobility solutions, also to establish trust and acceptance amongst end users. Extending the system domains beyond the vehicle through connectivity (short range or cellular) makes cybersecurity a fundamental building block for trusted (digital) interaction of road users with each other, the infrastructure and cloud-based solutions/services. Systems for CCAM must be fail-operational and cyber-secure in their entire Operational Design Domains (ODD) guaranteeing a safe and secure operation of vehicles -independent of the respective security level the element or system has within its ODD.

Cybersecurity needs to be an integral part of the development process, with common aims and objectives, frameworks/architectures, and designs (including normal operation, decision making and actuation as well as anomaly detection).

Proposed R&I actions are expected to develop and validate methods and tools strengthening the security of CCAM solutions (vehicles, infrastructure, etc.). They involve specific security building blocks, which are ready-to-use in CCAM applications in vehicles, infrastructure with feasible communication protocols. As a system’s approach integrating vehicles, infrastructure, back-offices and mobility service centres is required, proposed actions must develop harmonised interfaces and protocols.

Further R&I actions have to address continuous assessment of the robustness and resilience of CCAM enabled mobility solutions versus cyber-attacks, malfunction, misuse or system failure of the systems in use.

Actions should consider the security value chain at each level – from vehicle parts up to the transport infrastructure including the related services (e.g. maintenance, mobility) and protecting the user’s privacy and guaranteeing data integrity and authenticity. Actions should propose easy to use and re-use of best practices in cybersecurity for CCAM (i.e. architecture, design and implementation patterns).

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

C5-D6-CCAM-09-2022: Artificial Intelligence (AI): Explainable and trustworthy concepts, techniques and models for CCAM

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 5 and 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.

Expected outcomes:

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

- Concepts, techniques and models based on Artificial Intelligence (AI) used for situational awareness, prediction, decision making and triggering of actions for time critical and safety relevant CCAM applications as well as for cyber threat detection and mitigation.
- A clear understanding of the capabilities, limitations and potential conflicts of AI based systems for CCAM.
- Increased user acceptance from an early stage, based on explainable, trustworthy and human-centric AI. Interactions with vehicles using AI should be understandable, human-like and reflect human psychological capabilities.
- Accelerated AI development and training for CCAM enabled by a relevant set of real and synthetic traffic events and scenarios.
- AI based CCAM solutions will evolve from reactive and/or adaptive system support into predictive system state awareness (including driver state and user diversity), decision-making and actuation, enhancing road safety especially in near-critical situations.

Scope:

The deterministic understanding and consequential design of assistance systems are mostly reactive or to some extent adaptive. In the transition from driver assistance systems towards fully automated systems, a critical aspect is the decision making (i.e. planning and acting), based on robust and reliable detection and perception. AI has a huge potential to advance this process.

Specifically, in more complex and dense traffic environments, highly automated driving functions will benefit from the system state prediction enabled by AI. Yet, the current state of technology using AI for CCAM has limitations regarding human-like actions, more specifically the intuitive, split-second (predictive) assessments and 'reflex decision making'. As such, any AI requires good integration into the overall system with close interaction and compatibility with the active safety systems (e.g. automated emergency braking).

For the development process, training is essential for the performance of unbiased AI. It requires sufficient traffic and event data under varying conditions from all over Europe, avoiding limited data sets. The current, mainly deterministic approaches for validation in automotive development will not be sufficient for future training and validation of AI-based or AI-supported functions, which will also need to be able to deal with complex issues as (un)intended miscommunication.

Proposed R&I actions must therefore address all the following aspects

- support the development and integration of AI in CCAM with explainable, trustworthy and human-centric concepts, techniques and models; this can be on vehicle level and on transport system level, where tactical and strategic links to traffic management and traffic conditions need to be established;
- address the knowledge gap on AI training and validation approaches as well as efficient and ethical approaches for data handling of increasing amounts of data;
- build upon existing and generated data for training and verification of AI supporting situational awareness in CCAM in more complex traffic scenarios (e.g. digital twins).

Specific automotive requirements on functional safety and security must be considered in the development process of an automotive-grade AI ensuring consistency with existing validation procedures.

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

C5-D6-CCAM-10-2021: Analysis of socio-economic and environmental impacts and assessment of societal, citizen and user aspects for needs based CCAM solutions

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 3 and 4 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)

<u>Expected outcomes:</u>

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

For Area A:

- A well-founded understanding of effects and impacts (positive as well as negative), benefits and costs of CCAM systems and services (short, medium, long-term).
- Methods and indicators to assess the impacts of CCAM solutions on mobility and wider socio-economic and environmental aspects (public health, land use/infrastructure need, accessibility, economy, employment, working conditions and required skills, energy use, air quality, carbon emissions, etc.)
- Definition of KPIs incorporating societal targets with individual mobility needs.
- Methods and tools for CCAM developers and manufacturers, authorities, municipalities and citizens enabling design and decision-making based on an integrated understanding of all its possible short, medium and long-term impacts, thereby avoiding negative rebound effects, such as discrimination or bias towards certain user groups.

- Input for the design and evaluation of CCAM partnership activities, in particular for the large-scale demonstrators (ex-ante and ex-post) and for public engagement activities aimed at realistically informing users of CCAM capabilities and expectations.

For Area B:

- Methods and measures that capture the mobility needs of European citizens in the context of economic, social and environmental objectives at national, regional and local levels and that provide guidance on how to engage with citizens on CCAM solutions aiming to address these needs.
- Robust and documented knowledge (e.g. knowledge maps) of users' and implementers' expectations, concerns and desires with regards to CCAM solutions for the mobility of persons and goods, with special attention to the needs of vulnerable users and under-researched groups. This knowledge is to be integrated into the design and development of CCAM solutions to support these specific needs.
- Tools that allow CCAM developers, deployers and public authorities to implement user-centred CCAM solutions that effectively contribute to societal targets, including equity, and the uptake of CCAM systems at regional level.
- Recommendations for large-scale demonstration projects to include user and societal aspects taking into account location-specific characteristics of the implementation area, such as local policy targets, population density, and cultural matters.

All the above expected outcomes should support the uptake of CCAM solutions (including acceptance and adoption).

<u>Scope:</u>

With the increasing digitalisation of road transport, CCAM solutions have the potential to deliver an improved quality of life, by increasing safety and providing more sustainable and inclusive mobility solutions. However, for these solutions to be successful, a comprehensive understanding of all effects of CCAM on individuals, society and the environment over time is needed. Moreover, the successful deployment of CCAM solutions will depend on their availability and accessibility to future users, including the deploying organisations, as well as on the willingness of the general public to use and accept future CCAM solutions.

Actions must address the activities either under area A) Analysis of socio-economic and environmental impacts of CCAM systems and services OR under area B) Assessment of societal, citizen and user aspects for needs-based CCAM solution development and deployment.

Area A: Analysis of socio-economic and environmental impacts of CCAM systems and services

The analysis of CCAM benefits and risks are, or have been, addressed in R&I projects, which resulted in the creation of several impact assessment frameworks and decision support tools. However, these are not sufficiently comprehensive and lack a higher-level systems approach to fully understand and assess the short, medium and long-term risks of CCAM solutions on societal and environmental aspects. The impact level of existing assessment tools varies: the analysis of accident risk of automated vehicles has been considered extensively, while the understanding of wider health and equity effects on users' mobility experience is much less mature.

Actions will enhance existing methods/frameworks or develop new, broader, more comprehensive and inclusive methods for the assessment of how CCAM solutions, systems and services impact mobility and wider socio-economic and environmental aspects to ensure that the design of CCAM solutions are tailored to evolving mobility and environmental needs.

The proposed actions should include all the following aspects:

- develop comprehensive impact assessment methods that cover the full range of effects of CCAM systems and services by taking a systems perspective, that includes e.g. effects on jobs, health, inclusiveness, environment.
- For these methods, existing KPIs should be reviewed and updated if needed. In addition, new KPIs need to be developed, to capture aspects like equity in terms of access to mobility, or sustainability. User expectations towards e.g. comfort, perceived safety, necessary digital skills and access to information should also be addressed with qualitative assessments (e.g. observations, surveys, interviews).
- ensure practical usefulness of these methods by addressing regional specifics within Europe, as well as the evolving needs and dynamics of a society in transition towards more sustainable and shared mobility for both people and goods.
- cover under-researched fields in terms of impact assessment of CCAM solutions, such as the inclusion of underserviced or socio-economically challenged geographical areas and specific population groups.

Area B: Assessment of societal, citizen and user aspects for needs-based CCAM solution development and deployment

The assessment of societal, citizen and user aspects of CCAM has been addressed in a number of Horizon 2020 projects[81], typically focusing on the acceptance of automated vehicles by drivers and the public, driver needs and trust, and ways to increase driver performance. Yet the assessment of CCAM solutions in terms of inclusiveness, equity and accessibility is lacking in most R&I projects, and rarely goes beyond considering gender, disability and age. Persons with different income levels, different digital experiences, literacy and access, as well as people living in rural or peri-urban areas, are examples of user groups that need to be included in these assessment criteria so that extensive analyses of user needs and expectations can be carried out.

The aim is to proactively consider all user groups and societal objectives in the design and development phases of CCAM solutions.

The proposed actions should include all the following aspects:

- develop and apply a systems approach for better understanding and considering user and societal needs, desires and expectations related to CCAM solutions, systems and services. A broad understanding of "users" is to be applied, including persons, public institutions such as hospitals and schools, organisations and businesses.
- analyse equity aspects related to the deployment of CCAM solutions in terms of e.g. income level and solutions for deprived or underserviced areas, digital access,

[81] SUaaVE (http://www.suaave.eu/), PAsCAL (https://www.pascal-project.eu), Trustonomy (https://h2020-trustonomy.eu/), Levitate (https://levitate-project.eu)

covering personal mobility as well as provision of supplies and necessities to end users.

- map the broad range of concerns and expectations concerning CCAM involving a variety of stakeholders (including citizens, communities, transport service providers, professional drivers, road transport operators, road authorities, vehicle and other industry) and disciplines, including SSH (social sciences and humanities) to invest in social innovation that can complement the deployment of needs-based CCAM solutions.
- define methodologies and mechanisms to communicate with future users/ citizens about CCAM aspects related to trust, ethics and acceptance
- develop tools that foster capacity building on CCAM among planners and decision makers to enhance their ability to influence solution design and development.
- provide guidance on how to align overarching long-term policy goals and societal ambitions with user needs.

To make sure that the proposed actions above reflect the realities of a society with changing mobility, digital and environmental needs, participatory processes with a wide and diverse range of future user groups, civil society organisations, citizens, experts, deployers and decision makers at various levels are strongly encouraged. The resulting methods and tools should therefore be designed and developed in a co-creation manner between authorities, municipalities and citizens, as well as CCAM developers and manufacturers.

In order to achieve the expected outcomes, international cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore, Australia.

C5-D6-CCAM-11-2021: Framework for better coordination of large-scale demonstration pilots in Europe and EU-wide knowledge base

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 5 and 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)

<u>Expected outcomes:</u>

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

- Comprehensive analysis of all demonstrated CCAM use cases and harmonised approaches for implementing future large-scale demonstrations in Europe.
- Common framework for large-scale demonstration pilots in Europe including the identification of common use cases and Operational Design Domains (ODDs) as well as the definition of a common taxonomy and tools for scenario assessment.
- EU CCAM common evaluation methodology building on the outcome and recommendations from Working Group 2 of the CCAM Platform[5]
- Test data exchange framework with a collection of best practices and guidelines, including specifications for data labelling (e.g. ODD definition) and common data

formats (aligned with ongoing standardisation activities) as well as tools and documentation to use them, a common openly accessible platform safeguarding ethical usage of test data in a transparent manner to improve cooperation across projects and stakeholders

- Harmonised conditions and processes for tests of CCAM systems on public roads, including criteria for a mutual recognition of procedures (building on the outcome and recommendations from Working Group 4 of the CCAM Platform)
- Common basis for CCAM Knowledge in the EU through an up-to-date and continuously maintained Knowledge Base on CCAM adapted to the needs of the potential members of the European Partnership on CCAM and all relevant stakeholders.
- Efficient and sustainable governance structure for the collection of CCAM Knowledge in Europe and globally, thus facilitating the engagement and contribution of stakeholders from all sectors and in particular exchanges and cooperation with and amongst EU Member States.
- Network and forum of experts in the different thematic fields of R&I on CCAM with 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.

Scope:

Many diverse CCAM related R&I activities, tests and large-scale demonstration projects are ongoing across Europe and coordination, knowledge and data exchange as well as harmonised approaches for implementing future large-scale demonstrations in Europe are needed to better exploit synergies between all these activities.

There is a need for a common and searchable baseline of CCAM, thus ensuring transferability of knowledge for future research, development and testing of CCAM.

The aim of this action is twofold:

- to improve the coordination of CCAM demonstrations in Europe by developing a European framework for testing on public roads including common approaches for evaluation and test data exchange for large-scale demonstration pilots in Europe.
- to expand, maintain and update the existing EU-wide Knowledge which should centralise information about stakeholders, CCAM related R&I programmes and projects in Europe and beyond.

Proposed actions must address Area A and Area B.

Area A: Framework for coordination of CCAM demonstrations in Europe

The numerous CCAM demonstration projects in Europe lack a common vocabulary and the impact assessments of these projects are often difficult to compare. If different methodologies lead to incompatible evaluations, it will be hard to get an overall picture on the socio-economic and environmental impacts across several activities.

Proposed actions should establish a well-structured overview of European evaluation methodologies and its testing instances (test sites, living labs, simulations, open road) and develop a common evaluation framework and methodology with common indicators for large-scale demonstration pilots. This will allow comparability of results, complementing evaluations and meta-analysis over multiple evaluation studies. It will thus allow maximizing the profits and ease spreading of the lessons learned across Europe. It will enable to assess the wider impacts of future CCAM systems and services, providing necessary input for decision and policy making by governments and industry. Links should be established with other initiatives developing methodologies and indicators for CCAM solutions in specific areas, in particular on societal aspects[82].

Actions should build on the outcome of the CCAM Platform WG2 [83] and on the methodologies and practices developed by past and ongoing R&I activities and gathered in the CCAM Knowledge Base[84] to establish common criteria for the preparation, execution and evaluation of all types of impacts of large-scale CCAM demonstrations in Europe, in particular common assessment indicators and methodologies.

Different parties involved in CCAM testing generate large amounts of test data (from in-vehicle or infrastructure). Actions should develop a test data exchange framework, which addresses legal and administrative aspects as well as technical aspects like data provision, access, protection of user data, and labelling of data and proper description of the data format. This latter includes describing objects, features and other road users around the vehicle, but also the driver and passenger whereabouts inside the cabin, efficient (semi)-automatic annotation processes and complex-label description in a large-scale data environment. As part of the labelling, a standardised and structured annotation model should be included.

Different national policy and legal frameworks make the organisation of cross-border testing difficult. To facilitate the development of both cross border testing and support authorities and in particular cities in organising piloting projects, a European framework for testing on public roads based on criteria for mutual recognition of procedures should be established. Proposed actions should establish links with UNECE and have very close cooperation with the EU Member States through the CCAM Member States Advisory Board, in particular regarding testing conditions and regulations and associated harmonisation aspects.

Area B: EU-wide Knowledge Base

Proposed actions should continue and extend the existing EU-wide Knowledge Base[85] on CCAM as the "one-stop shop" for the exchange of knowledge and experiences on CCAM in Europe and beyond and to promote existing and valuable datasets. The Knowledge Base

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[82] In particular C5-D6-CCAM-10-2022: Societal, citizen and user aspects for needs-based CCAM solution development and deployment

[83] Working Group 2 of the CCAM Platform focussing on the "Coordination & Cooperation of R&I and testing activities" has analysed key challenges and identified actions regarding the development of a common evaluation methodology (CEM) and has provided a first outline of a European CEM. During this process, it has been deemed valuable to develop a set of guidelines and establish a support team that can offer advice to projects on methodological aspects and for setting up an evaluation plan. More information on Working Group 2 of the CCAM Platform: https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3657

[84] See https://knowledge-base.connectedautomateddriving.eu/methodology/

[85] The existing Knowledge Base (https://knowledge-base.connectedautomateddriving.eu) has been established as the one-stop shop for CCAM knowledge in Europe, which is used by an increasing number of stakeholders from Europe and other regions of the world. It features a number of essential elements for the identification of future R&I needs, supporting the harmonisation of procedures and the transferability of best practices. These elements include past and present R&I projects (both on a European and national level), information on related regulation and national policies, strategies and action plans, guidelines and evaluation methodologies, data sharing, relevant terms, related events (including materials from past events)

should collect structured, up-to-date and targeted information on European and national large and small scale demonstration projects and testing activities, test sites, corridors and living labs with their features and capabilities, standards, testing and assessment methodologies as well as regulations, policies and programmes in the field of CCAM in Europe and worldwide.

It should provide a common and searchable basis of CCAM, thus ensuring transferability of knowledge for future research, development and testing of CCAM. A wider engagement of the stakeholder community in providing content and actively contributing to its future development needs to be ensured.

The Knowledge Base should also function as the key information tool of the future European Partnership on CCAM to support the development and updates of the Strategic Research and Innovation Agenda (SRIA).

Particular emphasis should be placed on:

- Extending the content about CCAM activities in Europe and globally and ensuring it is up-to-date and mapped
- Developing knowledge summaries and collecting background information about purposes and drivers behind testing and piloting activities, lessons learned, best practices, implementation guidelines enabling the translation towards actions and agendas by authorities, decision makers and the CCAM Partnership,
- Structuring information and adding specific information, in particular according to stakeholder's needs and priorities and developing targeted toolkits to support new stakeholders in setting up, running and assessing testing and piloting initiatives.
- Collecting common terminologies, methodologies, standards and procedures related to CCAM and promoting the implementation of common metadata frameworks and the FAIR data principles86 to support interoperability.
- Maximize the outreach of the Knowledge Base through newsletters, dedicated social media channels

In close cooperation with the future European Partnership on CCAM, proposed actions should establish a network of experts in different thematic fields of R&I on CCAM. Actions should provide a forum to facilitate the interaction of experts, the exchange of experiences, implemented technologies and solutions and practices, stimulate collaboration and cooperation between all parties involved in the CCAM European partnership and beyond. Actions should organise conferences and workshops on CCAM , in cooperation with the future European Partnership on CCAM.

Particular attention should also be given to international cooperation activities to stimulate the exchange and collaboration with partners from other regions of the world on common R&I challenges in the area of CCAM. It is important to establish close contacts with the CCAM Member States Advisory Board to ensure good support for feeding the Knowledge Base with up-to-date information.

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[86] Final Report and Action Plan from the European Commission Expert Group on FAIR Data, "TURNING FAIR INTO REALITY" - https://ec.europa.eu/info/sites/info/files/turning_fair_into_reality_0.pdf

Multimodal and sustainable transport systems for passengers and goods

Multimodal and sustainable transport systems are the backbone for efficient mobility of passengers and freight. In particular, the areas of infrastructure, logistics and network/traffic management play a major role in making mobility and transport climate neutral, also through the digitalisation of the sectors. At the same time, being vulnerable to climate change and other disruptions, resilience in these three areas must be increased. New and advanced infrastructures across all transport modes are required to enable the introduction of new vehicles, operations and mobility services. Furthermore, efficient and smart multimodal logistics are key for seamless and sustainable long-haul, regional and urban freight transport movements. Finally, dynamic multimodal network and traffic management systems are the "glue" of the entire transport network, for optimised door-to-door mobility of both passengers and freight.

The main expected impacts are:

- Upgraded and resilient physical and digital infrastructure for clean, connected and automated multimodal mobility;
- Sustainable and smart long-haul, regional and urban freight transport and logistics, through increased efficiency,improved interconnectivity and smart enforcement;
- Reduced external costs (e.g. congestion, traffic jams, emissions, air and noise pollution, road collisions) of urban, peri-urban (regional) and long distance freight transport as well as optimised system-wide network efficiency and resilience;
- Enhanced local and/or regional capacity for governance and innovation in urban mobility and logistics.

C5-D6-MSTS-01-2021: More efficient and effective multimodal freight transport nodes to increase flexibility, service visibility and reduce the average cost of freight transport

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of of between EUR 7 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 7-8 by the end of the project – see General Annex D.

Expected outcomes:

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

- More efficient, effective and sustainable management of goods and freight flows in (air)ports and inland terminals.
- Expanded throughput of the nodes thanks to increased operational efficiency and optimised use of assets and infrastructures, without expanding the physical facilities.
- Improved access to transhipment services at reduced costs.

- More visible and standardised services provided within the multimodal freight transport nodes, seamlessly accessible by end users to maintain continuous door to door tracking of freight locations and boost shifting cargo to more efficient and sustainable transport modes.
- Increased automation, digitalisation, standardisation and interoperability of processes, technologies and equipment, particularly intermodal transport units (ITUs) and cargo transport/transhipment procedures in multimodal freight transport nodes.
- Better integration of freight transport nodes into overall logistic chains.

Scope:

To achieve higher levels of efficiency and maximise the utilisation of the multimodal freight transport nodes' capacity, the proposals should research and demonstrate all of the following points:

- Building on previous EU and other funded projects[87], and enabling compatibility with legacy systems, demonstrate and quantify the benefits of using different intermodal transport units (ITUs) and innovative automated loading systems to support multimodal logistics operations. Further develop standardisation strategies on intermodal transport units also focusing on different modes and logistics operators, cargo transport/transhipment procedures, technologies and interfaces to enable flexibility, efficiency and sustainability of the transport system.
- In line with the strategy for EU international cooperation in research and innovation (COM(2012)497), international cooperation on standardisation of ITUs is encouraged.
- Building on previous and on-going Horizon 2020 and CEF funded projects[88] and the Digital Transport and Logistics Forum's findings[89], deploy and demonstrate advanced cooperative logistics IT solutions in actual operational environment (minimum at TRL 7) focusing on better integration of the nodes in overall supply chains and the accessibility and usability of node services in an automated/digital manner, with a user perspective approach. The deployed IT solutions should:
    - Provide full visibility of the standard services offered by the multimodal freight transport nodes, and by the companies operating in them, e.g. open and shared warehouses, terminal services, transhipment facilities, transport services from and to the terminals;
    - Providing better estimated and actual times of arrival and of departure through real time track and trace of the transport and goods, benefitting from standardised identification (e.g. RFID, new sensors) and improved positioning accuracy based on European GNSS[90];

[87] Horizon 2020 funded projects such as Clusters2.0 (http://www.clusters20.eu/), AEROFLEX (https://aeroflex-project.eu/), and Less than Wagon Load (http://lessthanwagonload.eu/).
[88] Horizon 2020 funded projects such as AEOLIX (https://aeolix.eu/), SELIS (http://www.selisproject.eu/), COREALIS (https://www.corealis.eu/), 5G-LOGINNOV (https://5g-ppp.eu/5g-loginnov/).
[89] Enabling organisations to reap the benefits of data sharing in logistics and supply chain, https://www.dtlf.eu/sites/default/files/public/uploads/fields/page/field_file/executive_summary2_reading__0.pdf
[90] Global Navigation Satellite System (GNSS), https://www.gsa.europa.eu/european-gnss/what-gnss

- Provide automated decision support system functionalities to optimise the supply chain overall performance and its resilience against disruptive events (including pandemics);
- Ensure system compatibility of solutions with legacy systems;
- Ensure the resilience of data and management systems to mitigate the consequence of accidental or malicious interventions;
- Address data ownership, confidentiality, governance and access rights;
- Facilitate greenhouse gas emissions reduction through, for example, smart scheduling and information on expected port arrivals times to support slower sailing speeds.

- Capitalising on previous Horizon 2020 projects[91], demonstrate the effectiveness of new business models and collaborative approaches - preferably supported by the IT infrastructure and solutions outlined above - able to support cooperative logistics operations with focus on the provision of open logistics nodal services. The business models should consider the legal constraints and include appropriate frameworks for contractual relations in collaborative environments. Based on the deployment of these new business models, identify concrete legal barriers and regulations at both European and national levels preventing their adoption and market uptake, and propose solutions and specific policy recommendations.
- Ensure compatibility with existing and emerging EU logistics standards such as the European Maritime Single Window environment[92] for maritime transport and the platforms for Electronic Freight Transport information[93] and with the outcomes of initiatives such as the Digital Transport and Logistics Forum (DTLF).

Social innovation is recommended when the solution is at the socio-technical interface and requires social change, new social practices, social ownership or market uptake.

C5-D6-MSTS-03-2022: Logistic networks integration and harmonisation through operational connectivity to optimise freight flows and drive logistics to climate neutrality

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 7 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a

Projects involving earth observation, positioning, navigation or timing data, services or technologies must make use of Copernicus and/or Galileo/EGNOS data, services and technologies. Other programmes or systems may additionally be used.

[91] Horizon 2020 funded projects such as ICONET https://www.iconetproject.eu/, and LOGISTAR https://logistar-project.eu/.

[92] Regulation (EU) 2019/1239 of the European Parliament and of the Council of 20 June 2019 establishing a European Maritime Single Window environment and repealing Directive 2010/65/EU.

[93] Regulation (EU) 2020/1056 of the European Parliament and of the Council of 15 July 2020 on electronic freight transport information (Text with EEA relevance)

	proposal requesting different amounts.
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 Outcomes: Project results are expected to contribute to all of the following expected outcomes:

- Freight transport and logistics companies evolve to operate seamlessly engaging with nodes, partners and customers in an effective way, thus achieving a better utilisation of the assets and other resources in the freight transport and logistics chain within Europe.
- Energy and emissions reduction potentials higher than 20%, based on the operative gains without needing to renew the assets, are demonstrated by the shared logistics networks (collaborative logistics).

Scope:

Integration and harmonisation of closed independent logistics networks and of clusters of networks (e.g. from different logistics service providers or different cargo owners) providing open and shared services to manufacturers and retailers focussing on intra-European flows, would enable to optimise freight flows at system level, thus overcoming operational inefficiencies (e.g. peak overloads, partially loaded or empty transportation, sub-optimal transit routing, waiting times, higher overall costs, inefficient asset utilisation, increased emissions) and driving climate neutrality in logistics.

Innovation actions will have to advance the adoption of technological, organisational and behavioural solutions in use cases and applications under the leadership of logistics operators with specific reference to stakeholders' preferences.

In pilot actions, two or more logistics providers or shippers' logistics networks should develop and demonstrate a systemic framework for connecting effectively their independent logistics networks (at least partially) pooling the demand of various cargo owners and develop a system of logistics networks in which assets and services, including synchro-modal services, are shared and flows are managed in a consolidated way demonstrating potential benefits. Proposals should address all the following points:

- Develop and demonstrate a robust and transparent collaborative framework with guiding principles to ensure operational connectivity of logistics networks (e.g. services, shared resources and assets, information and financial flows, etc.) under the lead of logistics providers and addressing governance and potential anti-competition law issues. Current independent closed networks gradually shall become connected networks with shared and open capabilities, including intermodal transport solutions in specific demonstrations.
- Through the pilot cases and demonstrators:
    - Identify and demonstrate potential gains of these logistics networks / systems of logistics networks compared to independent logistics networks in terms of emissions and energy consumption reduction and potential economic sound paths for uptake beyond the project duration.

- Identify main barriers and opportunities to achieve a system of logistics networks, propose solutions and pilot them to deliver guidelines for expansion and implementation.
- Address governance aspects (e.g. how to organise and expand the logistic network with other logistics networks willing to join or how to legally engage with users of these shared logistics networks services and capabilities) and propose actions to accelerate organic and jointly acceptable growth of these logistics networks.
- Identify possible business model addressing also revenue sharing.
- Identify and assess possible existing regulation (e.g. anti-competition) preventing or new regulation needed to enable this shared and holistic approach, by building on the results and outcomes of previous and ongoing projects and activities[94]. Develop guidelines to address specific concerns and propose specific recommendations that should be considered.

- Identify and assess the main drivers and barriers towards horizontal collaboration in terms of organisational cultures and frameworks of the logistics service providers and the transport operators. Propose solutions to overcome the barriers and recommendations on how to create the best conditions (success factors) to boost new logistics collaborations, maintain them and reap their benefits.

Social innovation is recommended when the solution is at the socio-technical interface and requires social change, new social practices, social ownership or market uptake.

C5-D6-MSTS-05-2021: New delivery methods and business/operating models to green the last mile and optimise road transport

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 7 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action

Expected outcomes:

Project results are expected to contribute to [all/some] of the following expected outcomes:

- Take up and upscaling of innovative, best practice and replicable safe and sustainable last mile solutions in the living labs[95] involved in the proposals, while facilitating the common lesson drawing and learning at European level, in order to contribute to the

[94] E.g. Digital Transport and Logistics Forum www.dtlf.eu,, Collaboration Concepts for Co-modality (CO3) http://www.co3-project.eu/., NexTrust

[95] At least three cities/living lab

priorities of the European Green Deal, which stresses that ‘’transport should become drastically less polluting, especially in cities.”[96]

- Develop solutions for logistic hubs and micro consolidation centers and space management in cities. During the assessment process of possible locations for micro consolidation centres and micro hubs cooperation with local authorities is required. . Locations should be checked against the sustainable mobility plans of the concerning city.
- Test and deploy micro-consolidation centres as well as new delivery methods (including but not limited to e-cargo bikes) in at least 3 cities/project. The establishment of energy savings objectives (e.g electricity) regarding micro-consolidation centres in relation other traditional strategies could also be included.
- Optimise loads and reduce empty miles through dynamic routing, load policies, multi/single-brand parcel lockers and boxes,.
- Demonstration of cleaner modes of last mile transport for urban and peri-urban deliveries in the living labs involved in the projects (as listed in the scope part below).
- Increased quality and liveability of urban and metropolitan areas by reducing road risk, congestion, air and noise pollution.
- Improve knowledge of user needs, habits and preferences in terms of deliveries by collecting and sharing information amongst public authorities and private companies aiming at clustering users while respecting GPDR.

Scope:

The large scale introduction and application of cargo bikes, in urban and peri-urban areas has shown to be a game changer for cities: the image of cycling improves; general levels of cycling increase (both for freight and passengers); urban space is used more efficiently; air quality, noise and safety levels as well as quality of life improve. However, this innovative solution is present in only a few cities and at best in the starting phase in other European cities. Its full potential has not been achieved in any European city.

The aim would be addressing both methodological and vehicles aspects to help optimising last mile deliveries, where the benefits and how it can be replicated across several cities.

Demonstration of cleaner modes for last mile transport vehicles such as, electric cycles (2/3/4 wheels), bikes and cargo bikes (including investigating the use of Fuel Cell Cargo Pedelecs) in combination with the testing of innovative tools such as dynamic e-routing, load policies, multi/single-brand parcel lockers and boxes, micro consolidation centres and zero emission freight in the urban context to measure their effects on optimisation (reducing empty miles), efficiency, and congestion reduction should be considered. Results could also contribute to better delivery technologies transforming the last mile such as camera-based object tracking, precise location brought by enhanced EU satellite navigation (GNSS) services, application of AI technologies and CCAM solutions to delivery services and advanced analysis based on

[96] https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

driver apps. It is recommended the establishment of energy savings objectives (e.g electricity) regarding micro-consolidation centres in relation to other traditional strategies.

Actions should focus on piloting cooperation with private logistics operators, local businesses and establish new models for addressing governance and management of logistics operations in urban and peri-urban areas. Projects should achieve effective and scale up potential and deployment of innovative and sustainable urban people and goods mobility solutions enabled by better governance and regulations, including procurement or white-label schemes as an efficient tool for achieving these goals.

A thorough evaluation, using the common ‘CIVITAS Process and Impact Evaluation Framework’ with a clear baseline in each city, should provide qualitative and quantitative information on the results of the local solutions implemented. The effectiveness of the proposed measures in achieving local policy objectives should be evaluated and the possible barriers to their broad take up and deployment identified, together with recommendations on how to overcome them. This should be accompanied by mechanisms for common lesson drawing and learning, within the project, between the projects funded under this topic and through the CIVITAS Initiative.

Proposals may include preparatory, take up and replication actions, research activities, as well as tools to support local planning and policy making.

A demonstrated contribution to the implementation of the cities’ Sustainable Urban Mobility Plans and Sustainable Urban Logistics Plans, without forgetting higher scales planning scope, is expected.

Funding for major infrastructure works is not foreseen. Proposals should plan for an active collaboration within the CIVITAS initiative. They should demonstrate that the proposed approaches are truly innovative and build on the results from previous research and demonstration actions in this area.

C5-D6-MSTS-06-2022: Urban logistics and planning: anticipating urban freight generation and demand including digitalisation of urban freight

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of of between EUR 7 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action

Expected Outcomes:

Project results are expected to contribute to [all/some] of the following expected outcomes:

- Take up and upscaling of innovative, best practice and replicable data driven logistics solutions and planning in the living labs[97] involved in the proposals, while facilitating the common lesson drawing and learning at European level, in order to contribute to

[97] At least 3 living lab cities should be in included/ winning project

the priorities of the European Green Deal, which stresses that ‘’transport should become drastically less polluting, especially in cities.[98] This action supports city sustainability targets such as climate neutrality, road safety, improved air quality, reduced congestion and better use of public space.

- Optimal mix distribution of land uses both in city centres and peripheries looking at the preferred rationales for achieving the best combination of residential, commercial, leisure and industrial space to reach the most sustainable mobility patterns according to the available and future transport supply and demand.[99]
- Valorisation of data and information gathered for urban freight to better understand the impact of e-commerce on non-sustainable delivery patterns as “just in time” deliveries are producing longer and more trips with more and emptier Light Duty Vehicles (LDV), potentially leading to more congestion, pollution, Greenhouse gas (GHG) emissions and road risk in urban areas.
- Improved local authority capacity in the managing and collection of data, estimation and measurements of the impacts achieved by new measures and if a regulation is needed to ensure this happening.
- Optimise the potential mix of strategically positioned land, owned by public authorities (unused railway tracks and marshalling yards, real estate, parking) or by logistics service providers in urban areas, for developing a comprehensive policy strategy integrating transport, logistics and land use. The scope of this exercise includes the roll-out of new modes (such as drones) and increasing use of sustainable modes (waterways and rail).Better understand the impact of increasing transport and logistics patterns on the climate and environment, resilience and robustness of the transport network and the urban infrastructure. This excersice addresses as well the increasing impact of new modes, such as drones, cargo bicycles and vehicles on alternative fuels.
- Optimize shared transport facilities for both passengers and goods through smart solutions.
- Improved space management and urban planning focusing on the “new normal” after the Covid-19 pandemic considering how cities are optimising their planning and allocation of space.
- Demonstrate economically viable and sustainable solutions driven by relevant technologies (e.g. real-time traffic information, space management, floating car data) and utilising models that can influence the convenience of consolidation, consistent with the full planning of loading and unloading spaces, to deliver the services and the goods.
- Defined and shared principles by main stakeholders (cities, logistics operators, couriers, real state and retail industries) for the development of safe and sustainable logistics and delivery models in cities addressing low emission zones/data collection

[98] https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF
[99] These patterns are data supported, by collecting and analysing freight data.

and usage/consolidation and space management/clean and alternative vehicles/stakeholders dialogue & sustainable urban logistics plans/ environmentally friendly e-commerce solutions.

Scope:

Assessing how urban space is being used and allocated enables to reduce the impacts on congestion, noise, road risk, air quality, GHG emissions as well as livability. At the same time the development and demonstration of purpose-oriented data collection on freight transport in cities to support cities' decision making towards sustainability targets such as climate neutrality, air quality, road safety reducing congestion and better use of public space need to be addressed.

Proposals should address dynamic space re-allocation for the integration of urban freight at local level and the impacts of how urban space is being used as well as the optimal mix of space distribution and of land uses. Proposals should analyse the potential of strategically positioned urban (or peri-urban) spaces to develop and implement a pilot demonstration, (but without interfering with parks, trees or other recreational green areas). The aim is to reduce the impact of freight transport and logistics on the urban fabric.

Projects could consider involving real estate companies, logistics service providers, together with cities, to develop sustainable business models for open and clean hubs/consolidation spaces in cities (for example using/sharing existing private locations such as underground private parkings in banks, office buildings and other potential available spaces in cities – while respecting security constraints), for dynamic space reallocation and inspired from the Physical Internet concept.

A more efficient policymaking on urban freight logistics requires cities to enhance their data collection capabilities, while private logistics or e-commerce (like food delivery) companies and services should be encouraged to share data, considering what are the useful data, how can companies be encouraged to share and systematisation of data. Potential applications are Urban Vehicle Access Regulations (UVARs), including Low Emission Zones (LEZ), smart parking and dynamic space management. A vast amount of transport data from different parts of the transport system currently remains unexploited. If these data were collected, contextualised, and combined more optimally, this would enhance machine learning models' ability to infer useful patterns from both historical and real-time data**.** Understanding barriers and opportunities as well as developing local capacity related to data sharing within the urban and peri-urban transport system could be a first step to encourage private and public organisations to share their transport data. Potential benefits of the data applications need to be checked on how they could support the optimization of sustainable mobility plans (SUMPs) and sustainable logistics plans (SULPs).

Also the role SME and their digital capabilities should be addressed throughout the projects.

A thorough evaluation, using the common 'CIVITAS Process and Impact Evaluation Framework' with a clear baseline in each city, should provide qualitative and quantitative information on the results of the local solutions implemented. The effectiveness of the proposed measures in achieving local policy objectives should be evaluated and the possible barriers to their broad take up and deployment identified, together with recommendations on how to overcome them. This should be accompanied by mechanisms for common lesson drawing and learning, within the project, between the projects funded under this topic and through the CIVITAS Initiative.

Proposals may include preparatory, take up and replication actions, research activities, as well as tools to support local planning and policy making. A demonstrated contribution to the implementation of the cities' Sustainable Urban Mobility Plans is expected. Funding for major infrastructure works is not foreseen. Proposals should plan for an active collaboration within the CIVITAS initiative. They should demonstrate that the proposed approaches are truly innovative and build on the results from previous research and demonstration actions in this area.

C5-D6-MSTS-08-2022: Smart enforcement for resilient, sustainable and more efficient transport operations

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 4 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- An innovative, efficient, consistent and resilient enforcement system thanks to the direct contactless access to real-time digitized information on vehicle, driver and cargo by competent authorities.
- A more competitive and fairer transport internal market thanks to the realisation of "compliance by design" and "compliance by default" principles.
- Optimisation of the use of human and economic resources and increased productivity for both, public control authorities and transport operators, due to reduced administrative burden and time, while achieving a very significant increased control efficiency and consistency.
- Improved transport workers social conditions and increased attractiveness of the sector, by reducing the pressure put on them as the main subjects responsible for law compliance.
- Accelerate the deployment of e-government services by authorities and the uptake of digital solutions by transport operators for information exchange.
- Decrease number of transport accidents, incidents and fatalities linked to the higher levels of compliance with road transport legislation.
- Accelerate the deployment of innovative connected, cooperative and automated mobility (CCAM) technologies and systems for passengers and goods to increase safety and reduce environmental impacts.

Scope:

The research and innovation activites should provide innovative solutions for allowing the authorities to access directly and in real time all relevant information required under the different pieces of legislation in "one click". In particular, that should include social rules (such as Regulation No 561/2006 on Driving times and resting periods, Regulation (EU) 165/2014 on the Tachograph and Directive 2006/22/EC as regards enforcement requirements for posting drivers in the road transport sector), market rules (such as Regulation 1071/2009 on access to the occupation of road transport operator, Regulations 1072/2009 and 1073/2009 on access to the market for freight and passenger road transport, Directive 96/53/EC on weights and dimensions of certain road vehicles, Directive (EU) 2016/797 on the interoperability of the rail system, Directive (EU) 2016/1629 on technical requirements for inland waterway vessels, and Directive 2005/44/EC on harmonised river information services (RIS) on inland waterways in the Community), as well as safety legislation (such as Directive 2006/126/EC on driving licences, Directive 2003/59/EC on the certificate of professional competence of drivers, Directive 2007/59/EC on the certification of train drivers and Directive (EU) 2017/2397 on the recognition of professional qualifications in inland navigation).

Research and innovation actions will also have to bring together stakeholders at various level, from supply chain (e.g. manufacturers, retailers, freight forwarders and logistics service providers), transport services (e.g. transport operators, enforcing authorities) and infrastructure networks (e.g. road / rail / inland waterways operators and transport node public authorities) to ensure a truly integrated approach.

The technical solutions should take into account the work done in the Digital Transport and Logistics Forum[100] and in its subgroup on electronic documents in particular, and build on the existing electronic databases and exchange of information platforms (RESPER, ERRU, TACHONET, RIS, IMI, eFTI, etc.), as well as privately developed tools already in place, allowing for their interconnection or integration in order to provide seamless access and exchange of information under the "only once principle". They should also develop existing and/or new concepts and systems to incorporate the areas that are not yet covered by such electronic databases and platforms. The aim is to achieve a comprehensive ecosystem for smart transport enforcement that is tested and proved to be viable, economically and technically, and allows for future integration with relevant information exchange systems in use or considered for deployment in all modes of transport, as part of a wider multimodal transport information exchange environment.

The research should also provide assessment and recommendations on ensuring that there is a business case for the operators to make the information available electronically to the authorities, and for the authorities to accept it and implement the means to use this information in line with the "once only principle". Recommendations could eventually include the need for legislative measures to support the uptake of the digital and communication technologies for smart enforcement.

Furthermore, the research should consider the business case and conditions for reusing administrative information, where relevant, for the purposes beyond proving legal compliance. This includes, for instance, for compiling statistics, informing research, assessing the use of infrastructure, optimising logistics operations and maximising utilisation of assets.

C5-D6-MSTS-09-2021 Climate resilient and environmentally sustainable transport infrastructure, with a focus on inland waterways

Conditions related to this topic	
Expected EU contribution per	The EU estimates that an EU contribution of EUR 6 million would allow these outcomes to be addressed appropriately. Nonetheless, this

[100] https://www.dtlf.eu/

project	does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action

Expected Outcomes:

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

- Ensure navigability for inland waterways by assuring at least 50% capacity during extreme weather events.
- Enhance land/sea/infrastructure resilience to extreme weather and human caused events by assuring at least 80% capacity at network level during the disruptions.
- Contribute with at least a 20% 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) during construction, maintenance, operation and decommissioning of the infrastructure by at least 20%.

Scope:

Transport infrastructure is vulnerable to climate change and other natural or human caused disruptions. Maintaining an elevated infrastructure reliability and performance is crucial for increasing the resilience of the transport system. Low or excessive precipitations and temperatures extremes put a strain on transport infrastructure, lowering its performance and capacity, exacerbating its vulnerabilities and raising safety concerns. At the same time when focusing at a resilient and performing transport infrastructure its environmental footprint and resource and material consumption should be reduced to a minimum. The goal is smart, green, low-maintenance and climate-resilient infrastructure.

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. The proposals will develop and validate new solutions to increase efficiency, inter-modality, resiliance, safety and security of the transport system, for passengers and freight Proposals should address all of the following aspects: Particular attention should be paid to inland waterways:

- Solutions for ensuring the performance of inland waterways during periods of low or excessive precipitations (as they are primary reasons blocking smooth functioning of this type of transport infrastructures).
- Building on the outcomes of previous EU funded projects, solutions for ensuring the performance and safety of land transport infrastructure and ports during extreme weather and man-made events. Development of strategies for increasing the capacity of resilient infrastructures during disruptive events. Interconnection of infrastructure health monitoring, traffic management and emergency management systems to support informed decision making during and after these events, also supporting

possible redistribution of passenger and freight flows to complementary infrastructures.

- Building on state-of-the-art solutions for surveillance and prediction of climate change effects, and identification of infrastructure points vulnerable to climate change, proposals should develop cross-modal strategies to 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.
- Together with stakeholders and end users at various level, develop and demonstrate innovative concepts and solutions to make operations for passenger mobility, freight transport and logistics supply chains more resilient to large-scale shocks and disruptions by enhanced planning, management and flow redistribution (considering also shifting to less carbon-intensive transport modes). Innovative solutions should contribute to lowering the environmental footprint and resource and material consumption. The goal is smart, green, low-maintenance and climate-resilient infrastructure, planned in a way that maximises positive impact on economic growth and minimises the negative impact on the environment, promoting environmentally friendly modes of transport and leading to the reduction of transport emissions. Development of standard models and procedures to foster the implementation of resilient methodologies from design and construction and throughout the life-cycle of the infrastructure.

Proposals must consider at least two pilot demonstrations in operational environment (minimum at TRL7) in CEF corridors, one for inland waterways and a second one for land infrastructure. Proposals should also consider results from previous calls on infrastructure resilience[101] and sustainable construction.

C5-D6-MSTS-11-2022 Accelerating the deployment of new mobility services for the next decade

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution between EUR 8 and 10 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action

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

[101] EU funded projects such as RESIST, FORESEE, SAFEWAY, PANOPTIS

Developing and pilot testing at least three new business models scenarios based on collaboration platforms or public-private partnerships/project that will contribute to:

- congestion and air pollution reduction, reduced road risk, social inclusion, accessibility in each city(living lab)[102];
- increased share of new and shared mobility services (NMS) in the modal distribution, e.g. by 25% compared to a realistic baseline and financial viability of services;
- integration of new and shared mobility services with public transport – where possible (e.g. filling service gaps and off-peak periods), in at least three collaborative use cases/living lab that will facilitate data sharing and connectivity with remote/peri-urban areas;
  - (Re-)Designing transport infrastructure [103] or upgrading/reusing existing infrastructure elements (e.g. street profile/layout, intersection/junction design, priority corridors/lanes, dedicated parking, charging/docking stations, street surfaces/pavements, etc.) to accommodate new mobility modes, patterns and behaviours with highest safety levels while being resilient to various climate conditions;
  - Developing results based policy recommendations/each project in line with the Sustainable Urban Mobility Planning guidelines, to increase the understanding and take-up of new mobility services by local/regional authorities and public and private mobility service providers .
  - Actively engage in communicating the common learning, lesson drawing, evaluation, dissemination and the exchange of knowledge and best practices, both within the project and with the wider urban mobility and transport community.

Scope:

New and shared mobility services have shown that they have the potential to meet urban dweller's needs while at the same time bring about a more rational use of cars. However, in order to succeed at delivering ''Mobility As a Service'' and address the challenges that cities face, high-quality, user centric, and reliable new mobility solutions need to be offered as a credible alternative to the private car, coupled with safe and integrated infrastructure.

The objective of this topic is to deploy new solutions and explore the adaptability of transport infrastructure to new and shared mobility services. Solutions that could be considered are: micromobility, including bike/scoter sharing, demand responsive transport, car-pooling or car sharing.

New and shared mobility services should be proposed in at least 3 living labs/project in integrated, complementary and reinforcing packages of urban mobility and planning measures and new technological solutions, combining "push measures" with "pull" measures.

The services deployed should enable the idea of a social optimum in mobility from several perspectives (including socio-economic, environmental, health, accessibility; gender and

[102] At least 3 living labs/project
[103] solutions must demonstrate that traffic congestion is not increased.

inclusion; and safety and security aspects) while considering the implications for transport infrastructure and urban design.

The new services should also be tested beyond the commercially interesting urban cores, providing low and zero emission solutions for car-dependent suburban, peri-urban and rural areas linked to specific needs of diverse target groups such as populations with no access to public transport or affluent communities dependent on the private car.

Projects should test new and shared mobility services in mobility management (such as for companies, schools, attractions). Innovative approaches that respond to the needs of a large variety of users (such as families with children, people living in remote locations, commuters, housing developers) are expected. The role of marketing and communication, and approaches based on the co-creation of solutions should be considered.

Equally eligible would be cooperative approaches with employers willing to enter in a pilot to test a MaaS type of service for their employees or with housing developers that are offering reduced parking spaces to residents and seek to offer smart and shared mobility solutions in return.

The proposals should also explore how the adaptation of transport infrastructure (e.g. bike-lanes or new street designs, profiles and layouts, etc…), promotes the use of shared, micro- and active- mobility, limiting risks and increasing safety while reducing transport congestion.

The results and impacts should be assessed using a wide range of indicators.

Public space redesign actions targeted by the awarded projects should not come at the cost of removing or deterioration of parks, trees or green recreational areas in the selected partner cities.

The potential adverse impacts some NMS may generate for example on high-density urban areas, on safety and security, travel demand, public transport use and traffic volumes, should be considered.

A demonstrated contribution to the implementation of the cities' Sustainable Urban Mobility Plans is expected. Proposals should collaborate with the CIVITAS initiative. They should demonstrate that the proposed approaches are truly innovative for the local context. Proposals should ensure that an appropriate geographical balance across Europe is achieved through twinning activities and other means to maximise impact without leaving anyone behind, and by demonstrating commitment of cooperation though their planned activities.

C5-D6-MSTS-12-2022: Advanced multimodal network and traffic management for seamless door-to-door mobility of passengers and freight transport

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex D.

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

- improved multimodal transport network and traffic management capabilities, facilitating seamless door-to-door mobility for passengers and freight;
- effective and resilient network-wide data exchange and new integrated data management systems for dynamic and responsive multimodal network and traffic management;
- tested and validated systems for enhanced prediction and resolution of network bottlenecks, substantially increasing safety, security, resilience and overall performance of the entire transport network;
- innovative tools and services for optimising mobility flows of passengers and freight in cities and other operating environments, cutting congestion, journey times and traffic jams across transport modes, and thereby significantly reducing emissions (CO_2, SOx, NOx, particles, noise);
- new governance arrangements for multimodal transport network and traffic management, in view of further regulatory and policy actions;
- high market adoption and transferability of innovations to different ecosystems.

Scope:

Advanced multimodal network and traffic management capabilities are essential for the efficient operation of the entire transport network and for seamless door-to-door mobility of both passengers and freight. This is even more pertinent in view of new mobility trends and technologies, connected and automated vehicles, new physical and digital infrastructures and innovative services. At the same time however, a number of challenges remain to develop validated concepts and leverage multi-actor data exchange, ensure interoperability of new technologies and develop interfaces across transport modes, as well as to design appropriate governance arrangements for relevant public and private stakeholders.

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), actions should address at least six of the following aspects:

- developing and carrying out validation for multimodal, dynamic, (cyber and physically) secure and resilient transport network and traffic management systems, leveraging state of the art technologies (e.g. artificial intelligence, high-performance computing, edge computing);
- demonstrating effective collection, analysis and use of network-wide fixed and variable data (e.g. using ICT and EU satellite-based information from vehicles, physical infrastructures and users) and developing integrated data management and monitoring systems, for effective and intelligent multimodal network and traffic management;
- developing new methods and tools for harmonised and comparable international monitoring of mobility demand, for passenger mobility and freight transport, including through survey data collection and big data processing, leveraging the opening of service providers’ databases to research and public authorities;

- conducting simulations for system-wide optimisation of demand/capacity balancing for multimodal passenger and freight flows, against foreseen (e.g. traffic disruption due to an important city-wide event) and unforeseen scenarios (e.g. major network/traffic disruption as a result of a hazard manifestation or compromise in transport safety due to a health emergency), to enable real-time prediction and balancing of mobility behaviour, as well as early problem detection and resolution;
- developing and testing network and traffic management visualisation and decision-making tools (e.g. using big data, artificial intelligence, machine learning), while taking into account regular mobility patterns (including soft modes) and user needs of citizens (including vulnerable road users and different gender groups) and businesses, as well as ad-hoc and flexible mobility-on-demand services, in the context of mobility/logistics as a service;
- demonstrating interoperability and enhanced interfaces of network and traffic management systems across stakeholders, transport modes and country borders;
- performing early pilot activities on multimodal network/traffic management, of limited scale and in defined environments, such as in the context of urban mobility of passengers and freight;
- conceiving, developing and preparing the introduction of next-generation multimodal network and traffic management services, provided by public and/or private stakeholders and operationalised at a centralised and/or decentralised level;
- develop and test implementable multi-level governance models, with roles and responsibilities for public and private stakeholders to share data and engage in transport network and traffic management functions, providing recommendations for further regulatory and policy actions.

Activities are expected to achieve TRL 5-6 by the end of the project.

In line with the Union’s strategy for international cooperation in research and innovation, international cooperation is encouraged.

<u>Safety and resilience - per mode and across all transport modes</u>

Safety and resilience are of primary concern for any transport system. The EU set ambitious targets in its 2011 Transport White Paper and the third Mobility Package. COVID-19 has been a stark reminder of the importance of resilience to external disruptions, particularly for transport. Research and innovation will underpin the three pillars affecting safety and resilience: technologies; regulations (alongside acceptable level of risks); and human factors (individual and organisational aspects, including interaction with automation). The approach will be risk-based and systemic, including transport means/vehicles, infrastructure, the physical environment (e.g. weather) and the various actors (e.g. manufacturers, regulators, operators, users) as well as all their interfaces, including certification and standardisation bodies. Specific issues per transport mode and synergies across modes will be addressed, in particular for safety culture, data-exploitation and safety/cyber-security interaction and fitness/effectiveness of regulations. Specific consideration will be given to high consequence/low frequency events (such as incidents or accidents related to passenger ships and planes) and emergency issues requiring fast-track research to accelerate safety assurance, implementation of mitigation measures and safe recovery of operations.

Synergies will be exploited across research at national, EU and international level together with national authorities, EU agencies and international organisations to improve rulemaking, safety promotion and oversight.

The main expected impacts are divided in three main subgroups:

Safety in Urban Areas/ Road Transport Safety

- Improved reliability and performance of systems that aim to anticipate and minimize safety risks, avoiding risks and collisions, and reducing the consequences of unavoidable crashes (mainly C5-D6-SAFE-01-2021**)**
- 50% reduction in serious injuries and fatalities in road crashes by 2030 (C5-D6-SAFE-01-2021 and C5-D6-SAFE-02-2022)
- Drastic reduction of road fatalities and serious crash injuries in low and medium income countries in Africa; safe design principles of the future road transport systems, better traffic flow in big cities, exchange of best practices and training (C5-D6-SAFE-03-2021**)**

Waterborne Safety and Resilience

- Ensure healthy passenger shipping by preventing and mitigating the spread of contagious diseases and infections.

Aviation Safety and Resilience

- Decrease number of accidents and incidents due to organisational/human/automation factors and external hazards in all phases of flight, also beyond CAT category (80% goal in FlightPath2050), while enabling all weather operations.
- Saving lives following a crash (post-crash survivability).
- Anticipate emergence of new threats that could generate potential accidents and incidents (short, medium, and long term).
- Ensure safety through aviation transformation (from green/digital technologies uptake up to independent certification).
- Maintain safety and resilience despite the scale, pace and diversity of new entrants.

Safety in Urban Areas/ Road Transport Safety

C5-D6-SAFE-01-2021: Testing safe lightweight vehicles and improved safe human-technology interaction in the future traffic system

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex D.

Expected Outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

For Area A:

- Safer but also lighter and circular vehicle structures
- Advanced vehicle concepts with higher compatibility between vehicles of different sizes and masses in dissimilar crashes
- Advanced structural designs tolerant to a wider set of crash angles
- Demonstration of a minimum number of crash tests designed to validate virtual testing for a large number of different scenarios
- Improved safety in future mixed traffic scenarios including an increasing number of automated vehicles

For Area B

- Reduced driver distraction as an important factor in road crashes.
- Intuitive and unobtrusive information of drivers and other road users about expected actions at any time.
- Safer mobility for all road users including the ones with impaired mental and/or physical capacity.
- Availability of human-centric adaptive interfaces and positive stimulation and utilisation of human abilities by new human-technology interfaces
- Improved validation methods for HMI.

Scope:

Actions should address the activities EITHER under area A) Testing safe lightweight vehicles OR under area B) Safe human-technology interaction in the future traffic system. Proposals should clearly indicate which area they are covering.

Area A –Testing safe lightweight vehicles

Automotive safety has significantly progressed in the last decades thanks to advanced modelling and testing capabilities and new structural concepts, as well as the introduction of active safety.

Future vehicles and their structures, however, will have to be lighter and lighter, and this means already an intrinsic reduction of safety when crashing with a heavier crash counterpart. Moreover, new structural concepts will need to be more and more designed with a circular use of materials in mind, and structures with mixed light materials and related manufacturing concepts (including casting and 3D printing of complex shapes, for instance in energy absorbers or highly intergrated structural components) will be widely different from today's mostly sheet steel based concepts. Advanced testing on crash, toughness, fracture and fatigue of new materials and concepts should be performed where relevant. A smart integration of these concepts shall lead the demonstration of a more sustainable body-in-white with at least a 10% weight reduction on already achieved results for multimaterial research structures.

In this context, the proposed actions should analyse the crash scenarios of the future, considering active safety devices but also their potential failure and the fact that for a long time there will be a mixed traffic situation where automated and semi-automated vehicles will share the road with normal “manually driven” vehicles and all types of unprotected road users.

This requires a new way of conceiving structures and their components, to ensure that all requirements are met at the same time and to further increase safety by including vehicle compatibility concept, like harmonised rigidity between light and heavy vehicles, so that the heavy vehicle helps the more vulnerable one in absorbing the impact energy. Standardised positions for crash absorbing elements should be addressed to ensure the best engagement scenarios, as well as multi-angle optimisation, to avoid that structures are optimised only for the exact test cases in regulation or in EuroNCAP tests. A significant number of crash tests is expected to be performed for validating the different scenarios.

Area B –Safe human-technology interaction in the future traffic system

Another challenge for the safety in future transport systems and services is the ever growing and intensified human interaction with ubiquitous digital content. The overload of various kinds of information from multiple sources can lead to increased driver or unprotected road user distraction and have negative impacts on road safety.

Human machine interfaces (HMI) with adaptive characteristics continue to be developed and new functionalities are continuously added, yet the impacts of those systems on the behaviour of drivers and other road users are not sufficiently known. Further research on the effects of such technologies in road transport safety is required.

These adaptive HMI systems can support a wide range of traffic users and definition of scenarios based on the mixed traffic and accidentology where needed. As such the applications are not limited to higher levels of vehicle automation. Therefore, they need to consider a wide variation of human capabilities and reactions as well as long-term mental and physical capacities (including disabilities and disorders) and instantaneous limitations in capabilities (collapse, illness, drowsiness, etc.).

In particular, the following aspects should be considered by future research:

- Design and development of intuitive, understandable, non-distracting and reliable adaptive interfaces for human-technology interaction in road vehicles minimising training needs for safe usage.
- Develop concepts of external interfaces, also considering the characteristics (for instance speed, direction) that are possible to interpret and understand by all road users.
- Understand long-term effects (physical and mental), potential risks and possible benefits for road users exposed to and actively using adaptive HMI technologies, and propose means to improve or maintain road user performance.
- Development of safety validation methods for new adaptive HMI technologies.

While this topic is open to research on all human-technology interaction in the road transport system, specific issues of the interaction of highly automated vehicles with their occupants and other road users are covered in topic C5-D6-CCAM-03-2022.

Typically, projects should have a duration of 36 to 48 months. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts or durations.

Social innovation is recommended when the solution is at the socio-technical interface and requires social change, new social practices, social ownership or market uptake.

C5-D6-SAFE-02-2022: Predictive safety assessment framework and safer urban environment for vulnerable road users

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex D.

Expected Outcomes: Project results are expected to contribute to [all/some] of the following expected outcomes:

For Area A:

- Harmonised, prospective assessment framework for road safety solutions (for policy, regulatory and consumer assessment)
- Comprehensive virtual representation of challenging scenarios in future road traffic
- Well-founded prognoses on the effects of new solutions on road safety

For Area B:

- 50% reduction in serious injuries and fatalities in road crashes by 2030, with a focus on measures addressing unprotected vulnerable road users
- Better prediction of road user behaviour
- Concepts and guidelines for safe inclusion of new means of transport into the traffic system
- Development of solutions that facilitate inclusivity of all specifically vulnerable rioad users, such as the disabled people, the elderly, and the children to the transport system by providing a safe environment for walking and cycling.
- Facilitation of modal shift to active and clean modes of transport, improving the health of road users and the quality of urban environments.

Scope:

A Safe System approach recognises that since accidents will continue to occur despite preventive efforts, it is a shared responsibility between stakeholders (road users, road managers, vehicle manufacturers, etc.) to take appropriate actions to ensure that road collisions do not lead to serious or fatal injuries. The safe system approach requires a systematic, multi-disciplinary, multi-sectoral, and multi-stakeholder approach which addresses the safety needs of all users; fatal and serious injury prevention, collision prevention and mitigation and post-collision care and aligns with other policies for co-benefits such as health, occupational health and safety, sustainable development and poverty reduction. In a Safe System approach, mobility is a function of safety rather than vice versa. It involves the implementation of system-wide measures that ensure, in the event of a collision, that the impact forces remain below the thresholds likely to produce either death or serious injury.

Area A – Predictive safety assessment framework

The road traffic system is changing with new technology, new means of transport as well as with regulatory and behavioural changes, and so will scenarios which are relevant for safety. Such future scenarios are not yet captured in accident databases. Traditional analysis methods and road studies can no longer predict the impact of new developments and new measures on road safety with an increased speed of technological development, but relatively slow penetration rates in the road traffic system. Also for already developed safety measures, scenarios need to be provided which cover more complex transport system levels where safety can be described in terms of risk and probability due to interplay between societal and technological driving forces as well as different stakeholder and user needs. A predictive safety assessment framework on higher system levels will support considerably the proactive management of road safety as an important principle of the safe system approach.

Virtual simulation allows for fast and extensive evaluation of safety measures even in scenarios which do not exist in real traffic yet. With growing computer power, safety assessment methods should therefore be extended to potential future scenarios and to the transport system level also allowing for the evaluation of socio-economic benefits. Such predictive assessment requires appropriate simulation environments and realistic models of all elements of the transport system (incl. human behaviour and traffic flow), which need to be harmonised to make them available for policy, regulatory and consumer assessment.

Within this context, actions should address the following aspects:

- develop new methods to efficiently predict the effects of new technology, new means of transport and regulatory or behavioural changes on road safety up to the level of socio-economic benefits
- further develop virtual models of the relevant elements of the transport system for which such further development is most urgently needed, and validate them
- analyse, based on selected examples, how the application of new technology and/or the introduction of new regulation will affect the remaining road safety burden, and how traffic and crash scenarios will change with their market penetration and/or enforcement respectively

Area B – Safer urban environment for vulnerable road users

A safe system strategy and targets to reduce accidents in urban areas inevitably should have at its core the safety of vulnerable road users. Vulnerable road users (pedestrians, cyclists and powered two wheelers) constitute almost 70% of the fatalities from road crashes in urban areas. Our society is characterized by an ageing generation, which is still mobile and more active in road traffic than in the decades before, therefore it is of high importance to improve safety in road traffic for elderly people by seeking solutions that would concomitantly address infrastructure and road user behaviour. A safe system strategy must also take into account the interactions between different modes of transport, especially the road intersection with trams, light-rail, commuter rail, including infrastructure and human factors of vulnerable users in relation to level-crossings and trespassing.

In this context, building on best practices (technological, non-technological and social), as well as ongoing projects and planned initiatives in the area of safe urban environment for vulnerable road users, actions should address the following aspects:

- Solutions to provide a safe environment for vulnerable road users through infrastructure measures and lifelong learning initiatives (behavioural change, training courses, road safety education from an early age)

- Identify specific mobility needs and public space design needs (in particular regarding women's perception of safety and people with disabilities, like blind people in shared spaces).
- Safe inclusion of new means of transport into the traffic system (including personal light electric vehicles, PLEVs, such as electric scooters and self-balancing vehicles and the safe transition to higher levels of automation e.g. automated public transport vehicles). Safety measures on the vulnerable road users' vehicles, improving stability, robustness and helping to prevent crashes overall
- Protective equipment (helmets, clothes, reflectors) that is effective, user friendly and likely to lead to higher usage rates. Possibilities of active equipment able to detect oncoming collissions and warn the VRU should be explored.
- Improved detection mechanisms of vulnerable road users by other users and accurate prediction of their behaviour including at road intersections.
- Analysis of the most common causes of accidents concerning vulnerable road users and demonstration of applied solutions
- Provide clear guidance to cities and Member States on how to incorporate the vulnerable road users dimension into infrastructure planning and sustainable urban mobility plans especially for the aspects of safety, security and accessibility.

Actions should address the activities EITHER under area A) Predictive safety assessment framework OR under area B) Safer urban environment for vulnerable road users. Proposals should clearly indicate which area they are covering. At the same time, links will ideally be established between projects under both areas, so that solutions, concepts and measures developed under Area B) could be assessed using the framework from Area A).

Typically, projects should have a duration of 36 to 48 months. Nonetheless, this does not preclude submission and selection of proposals requesting other durations.

Social innovation is recommended when the solution is at the socio-technical interface and requires social change, new social practices, social ownership or market uptake.

C5-D6-SAFE-03-2021: Radical improvement of road safety in low and medium income countries in Africa

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Research and Innovation Action (RIA)
Technology or societal readiness level	Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex D.

Expected outcomes:

Project results are expected to contribute to [all/some] of the following expected outcomes:

- Contribute to the global target of 50% fewer road fatalities and serious injuries by 2030 in low to medium income countries in Africa
- Contribute to implementing the recommendations of the Road Safety Cluster of the African-EU Transport Task Force adopted in 2020
- More effective design of road safety practices, measures and policies in the targeted countries ; establishment of the safe system approach in national road safety strategies
- In line with the Sustainable Development Goals and with the principles of the Joint EU-Africa Strategy (JAES), the activities to be implemented should contribute to the improvement of road safety and traffic fluidity conditions in Africa, ultimately saving thousands of lives and lessening the human, social and economic burden of road accidents.
- The reinforcement of endogenous African capabilities with a view to long term sustainable progress in the fight against road casualties and for a more efficient and sustainable transport system.
- The dissemination of European know-how and the deployment of sound technical and governance solutions. In particular, the outcomes of the SaferAfrica action should be included (in particular the African Road Safety Observatory).

Scope:

Over 650 road deaths per day occur on African roads and unless measures are taken, road crashes in Africa are projected to increase by 68% over the next decade. African road traffic death rates are the highest globally and more than four times higher than the European average.

Building upon the work and activities already undertaken at EU level in this area, including the Safer Africa project and in line with the recommendations of the Road Safety Cluster of the African-EU Transport Task Force adopted in 2020, R&I is needed to create a strong analytical base and to develop and assess, with local partners, the implementation of small scale system pilots and its various components, at city, regional, national and continent level. Actions should contain the sharing of knowledge and best practice, data analysis, infrastructure for effectively reducing road deaths in Africa.

To address this challenge, proposals should address all of the following:

- In-depth road accident investigations should be carried out at least in selected areas/countries to be able to find evidence of the underlying contributing factors behind accidents, whether related to the road user, vehicle, traffic environment or the traffic system
- develop an innovative approach to promote the Safe System approach in selected African countries, enabling the exchange of data, methodologies, training, knowledge and best practice with particular focus on leading road safety agencies, traffic system "owners" such as road authorities, the police, regulating and certifying agencies to support the preparation of their road safety strategies and targets.
- analyse the most appropriate road safety assessment methodologies and management systems, and define criteria for measuring future progress. Moreover, identify requirements for skills development and training of staff, and research and innovation needs, with a view to quick deployment of suitable solutions.

- design, develop and implement a series of small scale pilot demonstration projects to test the implementation of a safe system approach at different levels (national, regional, city), involving different local stakeholders (e.g. civil society organisations such as citizens' associations, and non-governmental organisations), local government bodies and institutions as well as private companies
- carry out an evaluation and assessment of the pilot demonstration projects that includes feedback from local actors, national and international stakeholders gathered through specific participatory workshops
- define guidelines detailing requirements and propose recommendations from the small scale pilot demonstrations useful for the implementation of a safe system approach to be up-scaled for the African continent (capacity building).

A balanced participation of European and African partners in these activities is expected, also with the aim of reinforcing endogenous African capabilities, and will be taken into account in the evaluation of proposals. Multinational international cooperation with relevant third countries is encouraged in order to leverage resources and impact.

Typically, projects should have a duration of 36 to 48 months. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts or durations.

Social innovation is recommended when the solution is at the socio-technical interface and requires social change, new social practices, social ownership or market uptake.

Waterborne Safety and Resilience

C5-D6-SAFE-04-2021: Controlling infection on large passenger ships

Conditions related to this topic	
Type of action	Research and Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 5 by the end of the project – see General Annex D.
Expected EU contribution per project	The EU estimates that an EU contribution of EUR 3 million would allow these outcomes to be addressed appropriately for the sub-topic of infection control and EUR 5 million for the sub-topic of healthy ship design. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.

Expected outcomes:

Project outputs and results are expected to contribute to allof the following expected outcomes as applicable for the two sub-topics:

- Communicable infections (Covid-19, influenza, norovirus) do not spread rapidly amongst passengers and crew on large passenger ships, in particular on cruise ships.
- Communicable infections on board large passenger ships can be detected systematically at an early stage and effective measures are put in place to prevent the spread of infection.

- Large passenger ships are intrinsically designed to prevent the spread of infection and to facilitate measures in case of detection to eliminate further spread.
- An evidence base has been established concerning the specific mechanisms facilitating the on-board spread of infection and the effectiveness of different mitigation methods.
- A knowledge base is publicly available concerning mechanisms facilitating the spread of on-board infection, mitigation measures and underlying evidence.
- Evidence based guidance for healthy passenger ship design is available to improve the design of ships which can help avoiding infections and facilitate the detection on board infections at an early stage, inherently mitigate the spread of infection and facilitate actions to prevent its further spread.

<u>Scope</u>:

Passenger ships and in particular cruise ships (with their high occupancy rates and elevated passenger and crew numbers of up to 8000 persons, close proximity of passengers and crews, high crew turnover with crews coming from many different countries, frequent port calls naturally implying common shore side excursions, and on-board activities with intense social interaction) have been implicated in the spread and multiplication of disease. Large and medium-sized cruise ships have seen a highly dynamic and sometimes dramatic multiplication of Covid-19 infections on-board and the disembarkation of several hundred infected (and often asymptomatic) passengers who subsequently became vectors for infection within the regions concerned and their home regions. In this context it needs to be kept in mind that cruise passengers often travel to and from the ship by air, adding to the potential spread. Passenger ships have also been hosts for the rapid spread of Norovirus illness, influenza and legionella infections. This can be particularly problematic for (generally smaller) passenger ships that undertake longer expedition-type cruises away from population centres, thus entirely or pre-dominently relying on on-board medical services and facilities. Europe as the world's largest and almost exclusive producer of large and medium-sized passenger and cruise ships and as home to a large number of important cruise destinations must ensure a healthy on-board environment which is also crucial for the viability and the sustainable growth of the business. Whilst guidelines to control the spread of on-board infections have been published, it is clear that these are not fully effective and there is a lack of an evidence base to underpin the effectiveness of the suggested measures for different infections. Important knowledge gaps continue to exist and so far the real effectiveness of different mitigation measures now deployed remains largely anecdotal.

To address these challenges, proposals will address one of the following two aspects and cover all of the tasks mentioned.

1. <u>"Infection control on-board large passenger ships - prevention, mitigation and management</u>".
    - Establishing a comprehensive scientific basis concerning the effectiveness of different prevention, mitigation and management measures.
    - Developing and demonstrating solutions for improving the prevention, mitigation and management of on-board disease and illness.
    - Cooperate and coordinate with other projects selected from this topic as well as other relevant actions such as the EU's "healthy gateways" action.
    - Outcomes and data to be made publicly available to facilitate the take up of best practices, also in function of vessel type and size, type of cruise and cruise

destination. A distinction should be made between large ferries as typically deployed in Europe and cruise ships.

2. “<u>Healthy ship design</u>”:

    - Applying a bottom-up evidence based approach address the functional and concept design of large passenger ships so as to reduce the on-board spread of infection.
    - Research should in particular address ventilation systems and their airflows, germicidal surfaces and disinfection practices, contamination control in all relevant ship areas, facilitating enhanced quarantine, process separation, the design of social areas including those for the crew, the design of crew work areas, especially pantries, laundries etc..
    - Innovative systems should be addressed to enable early stage detection of the spread of on-board infections such as for example employing AI, big data, smart sensors etc.
    - Cooperate and coordinate with other projects selected from this topic as well as other relevant actions such as the EU’s “healthy gateways” action.
    - Outcomes and guidance concerning healthy ship design should be made available so as to facilitate the take up of best practices by ship interior designers, shipyards, and equipment manufacturers.

Aviation Safety and Resilience

C5-D6-SAFE-06-2021: Safe automation and human factors in aviation – intelligent integration and assistance

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 6 or 7 by the end of the project – see General Annex D.

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

- Improved monitoring of human performance, system performance and external hazards, in order to pave the way to more automation in aviation while meeting Flightpath2050 safety goals.
- More adaptive and trustworthy human-machine systems and more intuitive interfaces, avoiding startle response or “automation surprise”, enabling intelligent assistance to all operators on the air and on the ground in all safety-critical situations and allowing fall-back response in case of severe system perturbations - including pilot incapacitation, cyber-attacks and/or broader operational system-wide failures.

- New crew and team configurations, including human-machine teaming, automation supervisory roles and distributed human crew (both airborne and on the ground) to ensure safety and optimise performance without leading to complacency or to loss of critical skills.
- Better prepared workforce and training, with smarter selection, qualification and training tools and methods to maintain high standards of safety and resilience, including advanced simulation for complex safety-critical events.
- Increased organisational and regulatory preparedness, safety culture and societal acceptance in the advent of more automation in aviation, from earlier integration of human factors and automation into design processes and safety case methods up to ensuring an appropriate level of human factors and automation competence in key organisations, including regulators.

Scope:

Activities should address a renewed safety focus on the teaming between the human and automation, given the steady increase in automation in the cockpit and in aviation at large, including for new airborne services and vehicles such as drones. When automation is unable to cope, control should be handed back safely to the human.

Prepare the next step-change in automation, artificial intelligence (AI), in two steps. Firstly, in the medium term with the role of AI as 'Digital Assistant', part of the team, earning the trust of the human operators and the flying public. Secondly, in the long term, with the potential of AI to take over operations. For the transition to digital assistant and ultimately to AI-run operations, develop a novel approach to Human Factors and to safety (and security) assurance methods and processes.

System transition issues should be addressed, to avoid an initial spate of 'automation-assisted accidents', as it happened at the last step change in the level of automation in aviation ('glass cockpits'), which nevertheless resulted in significantly improved safety.

Activities should consider the increasing complexity in aviation e.g. traffic growth expected back in the mid/long-term, more 'new entrants' as drones, more extreme weather events, more environmental constraints leading to more complex systems and operations. In such an evolving aviation environment it is needed to better understand and anticipate why incidents happen – the triggering events/hazards, the cognitive failures and the challenges at the human-machine interface – in order to learn the right lessons and then share them both internally and externally. This includes the impact of physical and mental wellbeing on human performance and safety, both in a positive sense (e.g. motivation, positive safety culture) and in a negative sense (e.g. fatigue, fitness for duty, skill loss, and complacency).

More focus is needed then on Human Digital Interface design and on integrating AI into human crews and teams, as a smart assistant to explain, accompany and support operators, in particular at safety-critical situations and to recover from emergencies. Developments should be applied to realistic operational and regulatory contexts while devising how to maintain safety culture and societal acceptance along with organisational and regulatory preparedness.

Activities should go beyond the state of the art and previous R&I activities, at least at EU level[104]. Activities should ensure no overlap but complementarity for integration with any other aviation activities, such as SESAR / Transforming the European ATM System partnership. The proposals may include the explicit commitment from the European Aviation Safety Agency (EASA) to assist or to participate in the actions[105].

Multinational international cooperation with third countries with relevant capacities in this domain can be foreseen in order to leverage resources and impact, provided that the respect of European IPR, interests and values is strictly guaranteed.

Synergies with other transport modes and safety/security critical sectors adopting more automation is welcomed, in particular on risk assessment and pre-normative research to ensure fit-for-purpose rulemaking and management systems and a high level of cyber-attack protection.

Social innovation is recommended when the solution is at the socio-technical interface and requires social change, new social practices, social ownership or market uptake.

C5-D6-SAFE-07-2022: More resilient aircraft and increased survivability

Conditions related to this topic	
Expected EU contribution per project	The EU estimates that an EU contribution of between EUR 4 and 8 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
Type of action	Innovation Action
Technology or societal readiness level	Activities are expected to achieve TRL 6 or 7 by the end of the project – see General Annex D.

Expected outcomes: Project results are expected to contribute to two or more of the following expected outcomes in order to contribute to Flightpath2050 safety goals:

- Near real-time proactive detection, communication and avoidance/mitigation of anomalies and hazards at the airport (e.g. on the runway, at ground-handling, etc.), in the atmosphere (e.g. extreme weather phenomena) and on-board (e.g. fire, electromagnetic interference, structural issues, etc.).
- Improved safety modelling and design of aircraft and airports to increase survivability e.g. in case of fire, crash, ditching … including impact of new fuels or energy systems.

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[104] Examples of aviation safety research projects available on:
- Projects For Policy (P4P) on Aviation Safety https://publications.europa.eu/en/publication-detail/-/publication/b4690ade-3169-11e8-b5fe-01aa75ed71a1/language-en/format-PDF/source-75248795
- Coordination-support action OPTICS2 https://www.optics-project.eu/narratives/

[105] https://www.easa.europa.eu/domains/safety-management/research

- Improved means and methods for reliable tracking of aircraft and timely evacuation, search and rescue of passengers and crew.

Scope:

Activities should contribute to maintain a high-level of safety in aviation by encompassing the evolution of external hazards with the evolution of aviation systems. Aircraft should be more resilient to external hazards and internal failures in all phases - from ground-handling, runway operations, up to flight and emergency operations. Should such rare events occur, the aircraft should be able to fly safely back to an airport, or, in the worst case, ensure the survivability of passengers and crew and their safe evacuation and rescue.

Increase the ability to predict and avoid or mitigate weather hazards, which remain one of the major challenges on the ground and in flight, such as thunderstorms, lightning strikes, turbulence and wind shear to icing, snow and fog, as well as emerging events such as drones incursion, and major events such as volcanic ash clouds that can affect large swathes of airspace. Prevent and handle electromagnetic interferences (including cosmic radiation) and fire events, triggered by internal failures or external hazards. Improve modelling and protections systems accordingly together with tools to assist the design and the certification process.

Advance systems and methods for reliable aircraft tracking and for safe evacuation, search and rescue of passengers and crew, including with new aerial means as drones. Advanced features of Galileo Search & Rescue operating service should be fully explored and exploited, if applicable.

Activities should go beyond the state of the art and previous R&I activities, at least at EU level[106]. The proposals may include the explicit commitment from the European Aviation Safety Agency (EASA) to assist or to participate in the actions[107].

Multinational international cooperation with third countries with relevant capacities in this domain can be foreseen in order to leverage resources and impact, provided that the respect of European IPR, interests and values is strictly guaranteed.

Actions involving earth observation, positioning, navigation or timing data, services or technologies must make use of Copernicus and/or Galileo/EGNOS data, services and technologies. Other programmes or systems may additionally be used.

Synergies with other transport modes and safety/security critical sectors is welcomed, in particular on risk assessment and pre-normative research to ensure fit-for-purpose rulemaking and management systems.

[106] Examples of aviation safety research projects available on:
- Projects For Policy (P4P) on Aviation Safety https://publications.europa.eu/en/publication-detail/-/publication/b4690ade-3169-11e8-b5fe-01aa75ed71a1/language-en/format-PDF/source-75248795
- Coordination-support action OPTICS2 https://www.optics-project.eu/narratives/

[107] https://www.easa.europa.eu/domains/safety-management/research

Other Actions

Scientific and technical services by the JRC

1. Clean Energy Technology Observatory

Development of a Clean Energy Technology Observatory that will monitor the EU research and innovation activities on clean energy technologies needed for the delivery of the European Green Deal; and will assess the competitiveness of the EU clean energy sector – and its positioning in the global energy market. It will build on the previous Low Carbon Energy Observatory and other related Commission activities.

Type of action: Provision of technical/scientific services by the EC Joint Research Centre (JRC)

Timeframe: 3rd quarter 2021

Total indicative budget: EUR 5 million from the 2021 budget

2. Energy markets analysis

To use and further enhance the METIS model for better understanding energy economy-environment interactions at national, EU and regional levels, with a particular emphasis on the detailed assessment of EU energy policy impacts on the power and gas systems and markets.

Budget: EUR 0.5 million

Timing: 2022-23

3. Energy scenarios

To use, further develop and maintain JRC's modelling capabilities for better understanding energy-economy-environment interactions at both the EU and global levels, with a particular emphasis on the detailed assessment of EU energy policy impacts. The tools to be developed, maintained and applied include POTEnCIA, GEME3 and POLES.

Budget: EUR 0.5 million

Timing: 2022-23

Public procurements

1. Study on development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels

The study will analyse the means which are needed to achieve the necessary industrial growth for advanced biofuels contribution to meeting the new targets for 2030 and 2050 under the European Green Deal by collecting industrial input directly from industrial associations operating in the alternative and renewable transport fuels sector, analysing and putting forward recommendations and a roadmap. The study will make an analysis on the actual status in capacity and supply of alternative to fossil fuels for transport, and on the demand, which will be created if different policy scenarios are applied to meet the new targets for 2030 and climate neutrality for 2050. The analysis will take into account all available alternative fuel options including those based on technologies still in development and demonstration stage today. Based on the results for the demand in drop-in advanced biofuels, the input of the relevant fuel producers will be collected in order to determine the necessary developments of the relevant industry in terms of actions and investments for meeting this demand in 2030 and 2050 with full compliance at highest standards with regards to socioeconomic and environmental sustainability. The study will provide factual evidence and rigorous analysis of industries outlooks and will define strategic research and innovation directions and a roadmap for the industrial developments. The overall output will be presented in a strategic report, which will be validated in a workshop with relevant industrial stakeholders and experts.

Type of Action: Public Procurement

Indicative timetable: 2021

Indicative budget: EUR 0.750 – 1.0 million from the 2021 budget

2. Study on Prize development for renewable energy systems (recognition and inducement prizes)

The study will investigate the potential candidates for prizes to be launched WP2023-2024 with the objectives to stimulate and accelerate the development and the market introduction of renewable energy systems. The scope of the work will cover the analysis of past prizes launched under Horizon 2020 and draw lessons to be learned, will establish criteria for prize selection in the field of renewable energy for both types, recognition and inducement prizes, and will draft aims and rules of contest for five prizes with the relevant stakeholders.

Type of Action: Public Procurement

Indicative timetable: Q22021

Indicative budget: EUR 0.70 million from the 2021 budget

3. Study on using pre-commercial procurements for drop-in advanced biofuel for commercial cargo-shipping and aviation

The study will address how to use pre-commercial procurements in the context of production capacities, target fleets and distribution infrastructure to create substantial uptake of drop-in advanced biofuel for commercial cargo-shipping and aviation which is essential for decarbonisation of the maritime and aviation sectors, yet those fuels are less competitive to fossil alternatives.

Form of funding: Procurements

Type of Action: Public Procurement

Indicative timetable: 2021

Indicative budget: EUR 0.30 – 0.50 million from the 2021 budget

4. Dissemination and information activities

Communication activities such as meetings, conferences, out-reach communication events/papers/materials and publications should support dissemination of knowledge and information to relevant stakeholders.

Type of Action: Public Procurement

Indicative timetable: 2021 and 2022

Indicative budget: EUR 0.1 from the 2021 budget and from the 2022 budget

5. Dissemination and information activities related to the EIC Prize Fuel From the Sun

Communication activities such as meetings, Grand Final, conferences, out-reach communication events/papers/materials and publications should support dissemination of knowledge and information to relevant stakeholders.

Type of Action: Public Procurement

Indicative timetable: 2021 and 2022

Indicative budget: EUR 0.1 in total for 2021 and 2022

6. Information, dissemination and logistic support for EU in Mission Innovation

The European Commission, on behalf of the European Union, joined the Mission Innovation (MI) in June 2016. MI is a global initiative that aims to reinvigorate and accelerate public and private global clean energy innovation to make clean energy widely affordable and it is one of the key strategic forum for the EU's international cooperation in clean energy RD&D. MI members committed to share information on their clean energy RD&D activities, double their governmental clean energy investments within 5 years, and encourage greater levels of private sector investments.

To guarantee continuation of MI initiative, and maintain the ownership of the activities the EC, on behalf of the EU, is actively engaged in and another set of activities it leads, a series of supporting services need to be covered, mainly the websites, information and dissemination activities and logistic support, etc.

Type of Action: Public Procurement

Indicative timetable: 2021 and 2022

Indicative budget: EUR 0.1 in total for 2021 and 2022

7. Information services for energy research and innovation policy development

An information platform is planned to be used to gain a better understanding of the energy research sector. Intelligence gained through the platform will help to establish priority areas, base policy decisions on hard evidence, and allocate resources optimally.

Type of Action: Public Procurement - 1 service specific contract in each 2021 and 2022, using an existing framework contract

Indicative timetable: as of 2nd quarter 2021, as of 2nd quarter 2022

Indicative budget: EUR 0.08 million from the 2021 budget and EUR 0.09 million from the 2022 budget

8. Smart Cities Marketplace

This action aims to continue the current well-established service portfolio of the Smart Cities Marketplace (knowledge-exchange, capacity building, matchmaking process) and expanding/supplementing it with a pan-European programme with certified experts and practitioners, which will provide hands-on help and know-how for making the much needed city-needs-led change a reality.

The Smart Cities Marketplace has established a large community of more than 6.000 smart city stakeholders across all relevant sectors (city administrations, industry, finance, research, EU and international initiatives, etc.) over the past few years.

Supported by and actively engaging these stakeholders the project fostered purposeful and tangible collaborations for the replication and upscaling of Smart City solutions.

Timing: tender launch in 4th quarter 2021 | project duration: 4 years

Budget: EUR 7 Million

9. Energy system modelling, optimisation and planning tools

Description: Provide local, regional, national and European public authorities and network operators, with an open source tool to allow them to better plan and optimise the development of renewable energy sources and the enhancement of infrastructure to meet the future energy needs in a geographical area.

- Advanced modelling tools to perform cross-border and cross- energy vector reliability-of-supply assessments on a long time horizon, where cross-sectoral disruptive innovations in industry, mobility and building sector can be included
- Building on existing open source models, the project shall further develop and validate an open source model of the components of the energy system and provide tools to integrate these component models into a system model to satisfy the (future) needs in a geographical area, thereby providing a planning tool for cost and emissions optimisation of the enhanced energy system at pan-European level. The aim is to better plan and optimise the energy generation and transmission and storage system to meet the (future) energy needs aggregated at the NUTS2 level; the distribution layer to individual energy users is not to be considered.

(More details in the draft Cluster 5 work programme 2021-2022, topic C5-D3-ESGS-03-2021)

Budget: EUR 3 to 5 million

Timing: call for tender in Q3-2021 | project duration: 2 to 3 years

10. Assessment of the competitiveness of clean energy technologies

This work will support the preparation of the annual Competitiveness Progress Reports required under the Regulation on the Governance of the Energy Union. It will build on the clean energy competitiveness framework and bring improvements, including on its social, economic, and environmental indicators, as well as its international dimension. It will also fill data gaps for specific technologies.

Budget: EUR 500.000 for up to 4 service contracts

Timing: Calls for tender in Q1-Q2 2021 – duration 1.5y

11. Technical and scientific assistance/ studies to support the development and implementation of the Renewables policy framework including heat and cooling, Biofuel, bioliquid and biomass related topics

Provision of scientific and technical assistance to the Commission needed for the analysis, development and implementation of the specific provisions of the RED linked to the technologies and markets of renewable energy.

Budget: EUR 1.2 Million

Timing: 2021

12. Response to lessons-learnt from recent accidents / incidents in Air Transport

Specific challenges:

The investigations of recent incident and accidents for commercial aviation (e.g. the Boeing 737MAX) have raised the need to investigate the use of new techniques, technologies and tools to enhance the end-to-end verification of complex systems, evolve airworthiness and flight standards and detect potential faults and improve the survivability of occupants in case of accidents.

Scope:

- Further develop the understanding of complex errors in critical or automated aircraft systems (e.g. air sensors, flight controls and the applicability of new techniques for design verification and real-time fault detection)
- Understand the risks for fire and smoke from lithium batteries in aircraft cabin, refinement of operational standards and procedures to mitigate these
- Develop comprehensive analysis and gather representative data for the assessment of aircraft evacuation issues, particularly for helicopter and VTOL1 ditching on water.

Contribution to EASA activities:

- Evolution of airworthiness standards (risk mitigations and regulatory compliance demonstration),
- Address EU MS safety investigation authority safety recommendations.

Impact: Introduction of innovative methods and solutions for safety management, Improvement of the European aviation safety system, Reinforcement of EU industry's leading position due to safety technologies

Type of action: Service contract

Budget: EUR 3.4 million

13. Enabling new concepts and technologies for Air Transport

Specific challenges:

Technological innovation for air transport requires the comprehensive evaluation of benefits, constraints, standardisation and deployment issues. Often, before new product approval, Aviation Authorities need to re-assess existing safety standards and certification processes to ensure their applicability to new technologies. Here the absence of up-front dedicated safety assessment and relevant data raises the risk of delaying deployment, or worse creating safety gaps with new products and processes. This research action concerns preparation for the safe introduction of several new concepts (reduced crew or single crew operations) and technologies (big data technologies, artificial intelligence, drones and U-Space3) culminating with new or evolved aviation standards and regulations, encompassing aircraft system certification methods and tools, operational procedures and flight training processes and systems.

Scope:

- Risk assessment framework for reduced crew and single crew operational concepts
- Development of certification standards supporting the introduction of artificial intelligence techniques for safety-critical aviation applications
- Introduction of new technologies for flight training devices (rules adaptation)
- New safety standards for drone autonomous operations and U-Space services

Contribution to EASA activities: Evolution of airworthiness and flight standards

Impact: Support of EU citizens and industry stakeholders through the safe and streamlined deployment of innovative products and operations

Type of action: Service contract

Budget: EUR 3.4 million

14. Solutions for Runway Safety

Specific challenges:

With the forecasted increase of traffic the importance of maintaining the highest levels of safety standards for runway operations remains paramount, in particular to address the risks of aircraft runway collisions and excursions. These risks are part of the key risk areas for commercial air transport as reported from the EASA Annual Safety Review4. The underlying issues include technical and operational issues, for instance incomplete situational awareness for runway operations, ineffective monitoring of runway surface conditions and the entry of erroneous flight parameters.

This research action will build upon previous developments for the prevention and mitigation of runway accidents and aligns to joint action plan prepared by Aviation Stakeholders.

Scope:

- Consolidation of best-practice and issues for the implementation of the ICAO 'triple one' concept (one runway, one frequency, one language)
- Introduction of new technologies for runway state assessment (assessing runway micro-texture)
- Enable mitigating means for frequent causes of incidents such as the entry of erroneous take-off parameters

Contribution to EASA activities: Contribution to Best Intervention Strategies, Evolution of safety standards

Impact: Improved technology and operations for the EU aviation industry, Reduction of runway incidents / accidents

Type of action: Service contract

Budget: EUR 2.1 million

15. Standards supporting the digital transformation of aviation

Specific challenges:

The fast-paced digital transformation observed in several industrial sectors is extending to aviation and air transport. The need to anticipate the changes and evolutions of aviation standards requires timely and upstream investigation, through several case studies, of the application of radically new concepts and processes for aviation products, processes and operations (such as machine-learning techniques, 'internet of the things'). This includes developing capabilities such as tools and methods for design, simulation (digital twins), verification and validation and their application to aircraft certification, regulatory approval and safety monitoring processes.

Scope:

- Develop a robust safety risk assessment methodology to support the identification and consolidation of safety hazards and their mitigation using numerical tools (the 'digital twin' concept)
- Prepare the roadmap for the next evolution(s) of airworthiness and maintenance standards for new digital applications and validate the new capabilities for the associated performance and risk assessment

Contribution to EASA activities: Roadmap for the changes to aviation standards

Impact: EU preparedness for the deployment of digital innovation in aviation and air transport

Type of action: Service contract

Budget: EUR 2.0 million

16. Development of New Aviation Health Safety Standards (for flight crews)

Specific challenges:

Current aviation standards have been built with duly consideration to occupational safety and health conditions affecting flight crew members. Nevertheless the lack of a comprehensive investigation centered on actual air transport operations of the potential hazards, incidents, causes and the appropriate mitigations, including new health monitoring solutions, represent a major obstacle for the evolution of those standards.

In particular the monitoring of the impact of diseases or health issues along the career of aviation professionals requires to investigate the state-of-the-art of medical research developments, the development of extensive health data sets and the validation of solutions for use in aviation environment.

As an example, a review of the current examination process of pilots living with HIV and HIV treatment revealed a lack of specific research on this subject.

Scope:

- Comprehensive assessment of health risks for aviation professionals in the fields of cardiovascular diseases and mental health, incl. risks following COVID-19 infection
- Investigation of aviation health safety issues (causes, incidence, mitigations) in the context of aircraft cabin environment, including air contamination events
- Evaluation of innovative solutions for health monitoring and protection in the context of aircraft operations
- Evolution of aeromedical standards for aviation professionals, incl. solutions for health monitoring of aviation professionals along their career, for pilots living with HIV

Contribution to EASA activities:

- Evolution of aeromedical standards,
- Comprehensive assessment of health safety risk and mitigations for air transport

Impact: Development of international health safety standards for air transport, Clarity and improvement of conditions for the EU aviation sector

Type of action: Service contract

Budget: EUR 1.7 million

17. Impact of Security Measures on Safety

Specific challenges:

The implementation of aviation security measures can have a direct impact on safety aspects of aerodrome or aircraft operations. Airport security, aircraft security, cargo and mail or inflight security are the areas where interdependencies are highly visible and where any security requirements should also consider possible impacts on and potential contribution to aviation safety.

The research action aims to provide new methods, tools and data for the effective performance of safety analysis while considering security measures, involving the different stakeholders concerned and to support the preparation of the evolutions needed in safety standards and to the aviation regulatory framework.

Scope:

- Assessment of the impact of security requirements on operational safety and performance, including development of new solutions and tools to ensure efficient assessment in the early phases of development

Contribution to EASA activities: Impact analysis of security requirements to safety standards

Impact:

- Enhanced standards for EU aviation industry,
- Contribution to international aviation standards

Type of action: Service contract

Budget: EUR 1.5 million

Grants to identified beneficiaries

1. Support for dissemination events in the field of Transport Research

Form of funding: Grant

Type of Action: Coordinate and Support Actions

Indicative timetable: biannual event (2024)

Indicative budget: EUR 1.5 million from the 2022 budget

Expected outcomes:

Project is expected to contribute to the following 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:

The action will prepare and provide support to the Transport Research Arena conference (TRA) to be organised in 2024 gathering road transport stakeholders for discussing political, industrial and research issues on a European and global level.

Proposals must 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 2024.

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) 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.

The proposal shall 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 shall give particular attention to gender issues.

2. Stimulating Road Transport research and innovation dissemination and implementation in Europe and around the World

Form of funding: Grant

Type of Action: Coordinate and Support Actions

Indicative timetable: Multiannual

Indicative budget: EUR 2 million from the 2022 budget

Expected outcomes:

Project's results are expected to contribute to the following outcomes.

- Strengthen and widely promote research and innovation activities, including among the public/civil society, via road transport dedicated events;
- Identify, highlight and disseminate the contribution from road transport, in particular from projects focused on zero tailpipe emission solutions, to the realization of the European Green Deal and the Paris Agreement;

- Provide a comprehensive overview of international developments in the field of road transport research to keep Europe competitive and successful;
- Increase of cooperation with road transport related national and international organizations and support of international EU activities in line with the UN Sustainable Development Goals;
- Contribute to identifying and analyse research and innovation areas for the future of road transport in the EU.

Scope:

The objective of this topic is to promote sustainable road transport in Europe and at international level. This action will contribute to a further harmonisation of research and innovation activities, and therefore contribute to the European Research Area, as well as to the European strategies for future transport systems. The action shall also help accelerating time to market of new mobility solutions, by stimulating a wider participation to EU activities and supporting European and worldwide dissemination of results. In addition, this initiative will support climate action and air quality improvement in line with the Green Deals targets and objectives, and contribute to the United Nations (UN) Sustainable Development Goals.

In line with these objectives, all the following aspects shall be addressed:

- Organisation of events, conferences, workshops and dissemination activities to present and discuss future technology and trends, results, exchange experience and foster innovation aspects of road transport research and innovation;
- Identification of actions to support road transport area, in particular in the fields of education, training and skills at EU level and standardisation and business models – mainly at EU level;
- Fostering of the links between European, national and (where feasible) regional programmes for road transport research, supporting coordination of activities with Member States;
- In the field of international cooperation, facilitating exchange between Europe and emerging economies in particular within Africa, Asia and Latin America;
- Identification of barriers for the deployment of research results and improvement of framework conditions at EU and international level, including development of pre-feasibility studies at least in the specific areas of “Urban zero-emission mobility”, “Air quality and climate change” and “Road safety”;
- Track global progress on urban electric mobility, air quality and road safety and support UN activities (e.g. with UN Habitat and UNEP), and ITF/OECD;
- Updating and coordinating research agendas and roadmaps in the field of road transport, in particular for urban mobility, road infrastructure, considering also road safety and logistics, taking into account relevant Horizon Europe partnerships and international activities in the field.

3. Support for SET Plan Conference

The European Commission will support the organisation of the annual SET Plan conference in Q4 2021, in cooperation with the Slovenian government, holding the EU Presidency of the European Union at the time.

Type of Action: Coordinate and Support Actions

Indicative timetable: 2021

Indicative budget: TBD

Legal entities: to be defined

4. Support to the IEA's Clean Energy Transition Programme (CETP) for emerging economies

Description: The EU currently provides a 3,5 MEUR funding for the IEA CETP, which develops cooperation with emerging economies (mostly China, India, Indonesia, ASEAN, Brazil, Mexico and South Africa) on energy statistics and data collection, energy policy analysis and capacity building, and innovation policy. This action is part of the EC/ENER international energy strategy and enables the EC to obtain better information on clean energy policies in these countries, while supporting the making thereof. In line with the international dimension of the European Green Deal, this action should be continued under HEU.

Type of Action: Coordinate and Support Actions

Full name: Organisation of Economic Cooperation and Development (International Energy Agency)

Address: OECD, rue André-Pascal 2, PARIS CEDEX 16 75775

Timing: from mid-2022 or 2023 until end 2024 or mid-2025

Budget: EUR 3 million from the 2022 budget

5. IRENA - Clean Energy Innovation Analysis & RE-MAP grants

Clean-energy technology innovation is expected to play an increasingly strategic role to accelerate the global sustainable energy transition. The development of new analytical approaches to tracking innovation and the expansion of relevant, publicly available datasets, will be necessary to support more effective and efficient clean energy innovation policy making that will deliver the solutions needed for the energy transition. While a significant amount of activity and data has been produced and made freely available on the front-end of innovation "inputs" (e.g. on public and private RD&D investments), there are still significant data gaps concerning innovation "outputs" (e.g. technology cost reductions, performance improvements, early stage deployments etc.). The International Renewable Energy Agency (IRENA) has developed significant capacity to support enhanced assessments of the effectiveness and efficiency of clean energy innovation policies of the EC, EC member states, as well as the main global players in clean energy innovation. The analytical experience developed by IRENA, with insights and data from its near global membership of 160 countries, coupled with its ability to convene experts and decision makers from around the world, has enabled the agency to produce detailed data resources and indicators relevant to clean energy innovation policy making, including on jobs, costs, patents, etc. The proposed activities build on that capability and aim to enhance IRENA's analytical and data-related capacity to inform clean-energy innovation policy making by: • Expanding the granularity of IRENA's renewable cost database (including levelised electricity costs), both in terms of technology value chain and geographical coverage (e.g. expanding data availability on EU Member States) • Strengthening datasets related to clean energy innovation, for example on output indicators like patents, trade flows and scientific publications. • Analysing clean energy innovation progress and trends based on innovation output indicators to improve understanding of efficiency and effectiveness of innovation policies. The activity above would enable IRENA to actively partner with the Mission Innovation initiative to support the implementation of the workstream on Tracking Overall Progress to Accelerate Clean Energy Innovation.

Budget: EUR 1 Million

Timing: 2021

Subscriptions

1. Contribution to Technology Collaboration Programmes (TCPs) of the International Energy Agency (IEA)[108]

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;
- Smart Grids (ISGAN);
- Greenhouse Gas R&D;
- Concentrated Solar Power;
- Photovoltaic Power Systems;
- Solar Heating and Cooling;
- Clean Coal Centre;

108 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.

- 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

Indicative timetable: as of 1st quarter 2021, as of 1st quarter 2022

Indicative budget: EUR 0.45 million from the 2021 budget and EUR 0.45 million from the 2022

2. International Partnership for Hydrogen and Fuel Cells in the Economy

Type of Action: Subscription

Indicative timetable: as of 1st quarter 2021, as of 1st quarter 2022

Indicative budget: EUR 0.03 million from the 2021 budget and EUR 0.03 million from the 2022

3. Voluntary contribution to the CEM Secretariat for Phase III (July 2022 – June 2025) and to participation in its initiatives and campaigns

The EU has been a consistent supporter of CEM over the years. Political support has already been expressed by the Commissioner for the extension of the CEM's mandate beyond June 2022, when the current mandate (Phase II) will expire.

The **CEM Secretariat**, together with the CEM Steering Committee, of which the EC is a member, now starts preparing the formalities and priorities of the new mandate (also referred to as CEM3.0). The CEM Secretariat will encourage members to put forward financial commitments by mid/end 2021 to underline their political commitment. Allocating this subscription in WP2022 will enable the EC to "lead by example". The current level of support should suffice.

Beside providing "voluntary contribution" to the CEM Secretariat, members are more and more expected to contribute financially to the running of **CEM initiatives and campaigns** (typically by contracted operating agents). This is certainly the case for the **SEAD** (Super-Efficient Appliances, 50k EUR/yr) and **Hydrogen** initiatives (20k EUR/yr), and eventually for the **Equal by 2030** campaign (10K EUR/yr). Therefore, the allocation of an additional amount is recommended

Timing: One-time payment in 2022 (second half)

Budget: EUR 0.6 million (CEM Sec, onetime payment) + 2 x EUR 0.08 million / yr = 160.000 EUR (for the initiatives)

4. 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.

Timing: 2021

Budget: EUR 80.000

5. IRENA Subscription

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.

Budget: EUR 56.000

Timing: 2021

Expert contracts