Working document

ISSUE PAPER

Towards the first work programme of Horizon Europe cluster 5 ('Climate, Energy and Mobility')

Please note that:

- **The impacts and issues listed in this document are preliminary.**
- **Not all impacts and issues listed in this document will be included in the first work programme.**
- **The number of issues and impacts listed in the document is not an indicator for the number of topics to be included in the first work programme, nor for the budget allocation to the different areas.**
- **The presentation of impacts and issues to be supported under European Partnerships is indicative and does not prejudge any future decision.**
- **This document does not address how cluster 5 will contribute to Missions.**

Contents

Introduction

The overarching driver for this cluster is the ambition to achieve climate neutrality in Europe by 2050, entailing the decarbonisation 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. Actions will support the implementation of the Paris Agreement, the European Green Deal (greater ambition for 2030 requires faster technological development and accelerated economic and societal transformation), the European Economic Recovery Plan and other EU priorities in the areas of climate, energy, and mobility. 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 in the wake of the Covid-19 crisis, contributing directly to the EU's Recovery Plan for Europe[1], and contribute to the Commission priorities 'An economy that works for the people' and 'A Europe fit for the digital age'.

Achieving deep decarbonisation of the energy and transport sectors while maintaining their competitive leadership and contribution to Europe's prosperity is crucial. As foreseen by the European Commission's strategic vision "A Clean Planet for All", decarbonisation – along with faster digitalisation and accelerated economic and societal transformation – will transform both sectors in the coming decades making them increasingly intertwined. At the same time, becoming a leading actor in fast-expanding global markets for sustainable technologies and services is imperative for the European economy and the energy and transport sectors in particular.

Research and Innovation will heavily influence the speed at which this transition 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 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 carbon-free alternatives for each GHG-emitting activity, 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.

[1] *Europe's moment: Repair and Prepare for the Next Generation*, EC COM (2020) 456 final, Brussels, 27 May 2020

1. 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 SDGs. Advancing climate science and creating a knowledge base is essential to inform the societal and social transition towards a climate neutral and resilient economy. Addressing the challenge of climate neutrality in Europe by 2050 will involve research that furthers our understanding of the changing climate and its implications, closes knowledge gaps, and develops the tools that support decision makers and the implementation of mitigation and adaptation solutions.

Building user-oriented and user-driven knowledge, supported by new generations of high resolution and integrated models will comprehensively 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 nature-based approaches. Furthermore, incorporating and further advancing research in social sciences and humanities, and behavioural science methodologies will accelerate societal transformation and behavioural changes of citizens and thus enable a just transition.

Expected impact

The activities implemented under this section will enable the transition to a climate-neutral and resilient society and economy through advancing Earth system science, decarbonisation pathway analysis, the development of adaptation solutions and climate services, supporting social science for climate and better understanding climate-ecosystems interactions.

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

a) Improve knowledge of the Earth system and the ability to project its changes under different socio-economic and natural drivers, allowing a better estimation of the impacts of climate change and the design and evaluation of solutions and pathways for mitigation and adaptation and related social transformation.

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

c) Strengthen the European research area on climate change.

1.1.1. Earth system science

The **main expected impacts** are:

a) Provision of the best possible science base, as required for the implementation of the Paris Agreement, in terms of monitoring, process understanding, attribution and projections of climate change for supporting the global stocktake and further policy development and decision making on climate change mitigation and adaptation on all relevant levels.

b) Sustaining European excellence and leadership in climate science and enhanced collaboration and coordination within Europe and beyond.

c) Raising of awareness and public engagement for climate action by contributing to highly visible assessement reports (most notably IPCC) and other means of knowledge dissemination.

For achieving these impacts, topics are considered addressing the following **issues**:

1. Improving basic understanding of the climate through the atmosphere and Earth systems, including complex interactions and feedbacks as well as linkages with the socio-economic systems.

2. Development of new generation, high-resolution Earth system models. Coordination with the "Destination Earth initiative" (concept under development).

3. Enhancing the integration or reconciliation of reported, modelled and observed greenhouse gas emissions, atmospheric and oceanic signals on different spatial and temporal scales.

4. Enabling ambitious and effective mitigation actions, through better understanding of GHG fluxes and other radiative forcers, carbon sinks and Earth system feedbacks.

1.1.2. Decarbonisation pathway analysis

The **main expected impacts** are:

a) Support to achieving the objectives of the Paris Agreement by provision of knowledge for the design or evaluation of climate action policies.

b) Support the realisation of the European Green Deal objectives and progress towards the SDGs through the simultaneous pursuit of climate action, biodiversity preservation, food security, resource efficiency and other goals.

c) Key contributions to IPCC, IPBES or the global stocktake under the Paris Agreement.

d) Increased engagement of civil society or business for climate policies based on better awareness of mitigation pathways and policy mixes through improved and better coordinated outreach and communication of scientific results.

For achieving these impacts, topics are considered addressing the following **issues**:

5. Development of next generation Integrated Assessment Models (IAMs) in support of global and regional climate action.

6. Integration of climate change impacts, biodiversity considerations and Earth system feedbacks into a common IAM framework.

7. Modelling and analysis of the circular economy in the context of mitigation.

8. Improved understanding of different CDR methods (C-cycle feedbacks, time scales, permanence, environmental and health impacts, land and energy demand); Developing MRV frameworks for CDR uptake at scale.

9. Evidence-base supporting the EU Green Deal; Comprehensive analysis comparing cost of action vs. cost of inaction, including high-end climate change scenarios and tipping points.

10. Improved knowledge of the potential contribution of negative emissions in stabilising, and lowering greenhouse gas concentrations; Improved knowledge of climate reversibility when returning from high future atmospheric CO_2 concentrations to a lower level.

1.1.3. Adaptation / Climate services

The **main expected impacts** are:

a) Increasing the resilience of the European society to climate change impacts through the provison of actionable knowledge on relevant spatial and temporal scales.

b) Increasing the coherence between climate change adaptation, mitigation policies, sustainable development or other co-benefits.

c) Supporting the goals of the EU Partnership on Biodiversity and the EU Adapation strategy, including through a better understanding of how natural and socio-economic systems interact in a changing climate.

d) Seamless high-quality information from near-term to long-term climate projections under different scenarios available to policy makers and other end users.

e) Strengthening the link between climate modelling and the provison of climate information into relevant sectors or end-users (e.g. through the development of user-centered climate services).

For achieving these impacts, topics are considered addressing the following **issues**:

11. Actionable adaptation options developed for particular contexts (regions, sectors and challenges).

12. Development of robust decision support tools for adaptation in Europe combining multiple lines of evidence (ESMs, RCMs, IAMs, observations), turning adaptation needs into an opportunity for transformative change towards a more resilient, sustainable and equitable society.

13. Higher resilience to extremes throughout Europe including the most vulnerable regions through the improved forecast quality of extreme climate-related events on a range of time and spatial scales and response options and strategies appropriate to the scale, likelihood and criticality of different risks.

14. Effective hybrid ("green", "blue" and "grey") adaptation solutions developed for different contexts, including tools to assess multiple-benefits and trade-offs compared to "pure" approaches.

15. Developing a pipeline of quality innovations that can be scaled up and/or replicated; Advance the socio-technical readiness of innovations that enhance resilience; Interactive information tools (such as apps) to better inform society and contribute to its transformation towards increased preparedness and resilience to climate change.

16. Assessing the effectiveness and impacts of a combination of small scale and local interventions with large scale solutions at lanscape/regional scales.

1.1.4. Social science for climate

The **main expected impacts** are:

a) Accelerate societal transformation, behavioural changes and changes in investment patterns needed to achieve decarbonisation and climate change adaptation, with view also to the biodiversity crises, pollution or the SDGs.

b) Increase communities' adaptative capacity.

c) Support the development and public acceptance of policies for a just transition to deep decarbonisation through better understanding of the distributional and adverse impacts of mitigation policies combined with climate change impacts and their effects across sectors, stakeholders and regions.

For achieving these impacts, topics are considered addressing the following **issues**:

17. Develop realistic scenarios and models for optimising the combined contribution of land to climate change mitigation, adaptation and biodiversity objectives. Develop incentive mechanisms to upscale changes in land management and workable models for effective and efficient monitoring of public goods benefits of land.

18. Social science for strategies in the context of climate change adaptation and resilience (better understanding of group and individual behavior in the face of slow-onset and unexpected impacts, piloting novel approaches at local scale).

19. Social science for a just transition towards deep decarbonisation (better understanding of the wider social, economic and political repercussions of the structural changes needed to support the fairer distribution and social acceptance of mitigation efforts and to achieve deep emission reductions, including climate change resilience consistent with the Paris objectives).

1.1.5. Climate-ecosystem interactions

The **main expected impacts** are:

a) Improve and use the knowledge on the contribution of Nature-Based Solutions (NBS) and biodiversity to climate change adaptation and mitigation.

b) Support to the restoration of biodiversity, ecosystems and their services, in particular carbon sequestration.

c) Support to the implementation of the EU Biodiversity Strategy for 2030 and the Paris ambitions and contribute to IPCC or IPBES.

For achieving these impacts, topics are considered addressing the following **issues**:

20. Restoring natural wetlands, peatlands and floodplains for climate change mitigation and adaptation-pathways, trade-offs and co-benefits.

21. Let nature help do the job? Rewilding landscapes affordable pathways for carbon sequestration, climate mitigation and adaptation and biodiversity support.

22. Unlocking knowledge on the contribution of NBS (including nature restoration & conservation areas) to climate adaptation and mitigation, and biodiversity.

23. Adapting forests and forest management to a changing climate: strategies, pathways and trade-offs.

2. Destination 2 – Cross-sectoral solutions

Many challenges regarding climate, energy and mobility are closely interlinked and must be addressed in a holistic approach, including with regard to their implications for citizens and society and making use of the social sciences and the humanities (SSH). This Destination covers issues within the scope of cluster 5 that have a particular strong cross-sectoral dimension[2], notably batteries, communites and cities, citizens engagement as well as breakthough technologies.

Expected impact

Activities under this Destination should set out a credible pathway for enabling the *"Clean and sustainable transition of the energy and transport sectors towards climate neutrality facilitated by innovative cross-cutting solutions"*. This entails in particular:

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 decarbonised 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 emergence of unanticipated technologies enabling zero-greenhouse gas and negative emissions in energy and transport;

[2] Hydrogen and fuel cells will be addressed through a dedicated institutional partnership and are therefore not included in this document.

2.1. 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. High performing batteries are an essential energy storage technology necessary for Europe to succeed in this transition. This can only happen through 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 long term technological leadership and industrial competitiveness in battery for energy storage and their use in many applications sectors.

The Partnership "Towards a competitive European industrial battery value chain for stationary applications and e-mobility" aims to establish best-in-the-world sustainable and circular European battery value chain to drive transformation towards carbon-neutral society. The Partnership ambition is to prepare and equip Europe to commercialize the next-generation 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.

In parallel, research will continue through Horizon Europe programme and cover technologies which are not directly related to the objectives of the partnership, crucial for sustainable transition of the energy and transport sectors towards climate neutrality by 2050.

The **main expected** impacts 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;

d) Developed end 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;

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 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.

For achieving these impacts, topics are considered addressing the following **issues:**

2.1.1. Future emerging technologies

1) Accelerated discovery of future battery technologies;

2) Embedding smart functionalities in cells;

3) Testing and validation of next generation future high performing battery concepts;

4) Work on promising technologies not involving critical raw materials.

2.1.2. Materials and advanced materials

5) Development of high performance anodes;

6) Development of high performance cathodes;

7) Development of new types of electrolytes;

8) Improvement of other components (separators, binders, etc);

9) Digitalisation and modelling;

10) Advancing knowledge of potential battery materials at nano and sub-nano scale.

2.1.3. Non Li-ion batteries for various applications

11) Development of batteries for non-automotive applications (including industrial applications and large-scale storage);

12) Increasing performance of post-li ion batteries;

13) Exploration and further improvement of potential close-to-market technologies.

2.1.4. Material and battery cell manufacturing

14) Development of equipment for battery manufacturing;

15) New eco-efficient manufacturing techniques;

16) Digitalisation and modelling for materials and manufacturing.

2.1.5. Refining, Recycling and circularity

17) Second life validation concepts;

18) Direct recycling and design for recycling concepts;

19) Techniques to improve material recovery rates;

20) New advanced refining techniques;

21) New sorting, handling and recycling concepts, including logistics.

2.1.6. Integration in mobility and stationary storage applications

22) Advanced Battery Management Systems for mobility and stationary storage;

23) Improving design and performance of battery energy systems;

24) Further reduction of costs of battery packs for mobility and stationary storage;

25) Enabling optimum use of stationary and EV batteries through interoperability, in complementarity with area Energy systems, grids and storage

2.1.7. Safety

26) International cooperation on incident database and response strategies for safety;

27) Fire and explosion prevention, suppression and mitigation;

28) Battery health monitoring systems;

29) Safety assessment standardisation for mobility and stationary applications.

2.1.8. Support activities

30) General support for regulation and standardisation beyond safety;

31) Support for development of R&I roadmaps, for setting strategic research agenda and for strengthening the European R&I community (regulation, standardisation, collaboration etc).

2.2. Smart and sustainable communities and cities

With more than 80% of the EU's population living in urban areas it is essential to adopt new system approaches to (re)design our spaces/cities, incorporating regenerative paradigms in an integrated urban agenda with a focus on energy & mobility systems, sustainable and carbon-free/low emissions built environment, contributing to the EU zero pollution and climate ambitions as well as to the 2030 Agenda for Sustainable Development (notably SDG11 for

sustainable, resilient, inclusive and safe cities). This should be supported through user-friendly and secure digital services, able to adapt to climate change also combined with hazards and to increase quality of living. Co-design and co-creation approaches with- and for society can help ensure uptake and deployment of solutions and guarantee nobody is left behind. Further to R&I activities described below, support will be provided to the co-funded partnerhip Driving urban transitions to a sustainable future. The partnership, through aligningment of nationally and regionally funded R&I agendas, efforts and investments, will support challenge-driven trans-disciplinary research and innovation, development, upscaling and uptaking of systemic solutions and capacity building to assist European cities in the design and implementation of transformative transition to sustainability and climate neutrality.

The main **expected impacts** are:

a) Enhanced sustainability, resilience, liveability, attractiveness, quality of life, well-being, accessibility, inclusion, diversity and equity;

b) Participatory, effective, accountable, inclusive and future-oriented decision-making for just urban transition towards sustainability, carbon and climate-neutrality and zero pollution of air, water and soil;

c) Fair and transparent assessment of progress of transition pathways, including assessment of their co-benefits;

d) Increase overall energy, resource efficiency and climate-(combined also with hazards)-resilience of cities and communities;

e) Toxic-free urban environment, including improved air and water quality and reducing cities'overall environmental footprint;

f) Diminished negative externalities of urban and peri-urban transportation: congestion, air and noise pollution and road collisions;

g) Improved modal share of sustainable and active transport modes such as walking, cycling and low- or zero-emission shared mobility;

h) Facilitated deployment of sustainable and clean modes of transport;

i) Enhanced local and/or regional capacity for governance and innovation in urban mobility and urban logistics;

j) Accelerated uptake of innovative and smart mobility solutions in key areas such as public transport, mobility management and planning;

k) Sector integration, CO2 reduction, better air quality, better performing grids, enhanced competitiveness of EU industry for climate neutral and resilient citiesEnhanced interoperability, sustainability, trust, standardisation and uniformity of cross-sector digital solutions, infrastructures and services; cross-sectorial synergies and new value chains.

For achieving these impacts, topics are considered addressing the following **issues**:

2.2.1. Sustainable, inclusive, human-centred and carbon-neutral zero emission Urban Mobility and transport systems

1) Zero-emission public transport and active modes (walking and cycling) as backbone of urban mobility;

2) New and shared mobility services;

3) Inclusive and accessible transport system and public space);

4) Innovative urban mobility governance;

5) Innovation in logistics to reduce air pollutant and greenhouse gas emissions in goods delivery.

2.2.2. Innovative Urban governance, business and financial models

6) Urban regeneration, including for social housing, second order peripheral cities and shrinking cities;

7) Cities resilient to climate change events combined with other hazards.

2.2.3. Social innovation for urban decarbonisation

8) Harnessing potential of social innovation, citizens engagement, diverse lifestyles for urban decarbonisation.

2.2.4. Monitoring and assessment of urban transitions

9) Transparent and inter-comparable assessment of progress in just urban transitions.

2.2.5. Urban planning and design

10) Integrated human-centred urban planning and design for equitable, just and optimal use of space and infrastructures Preventing and removing accessibility barriers in the built environment;

11) Integrated planning on the urban-rural nexus and metropolitan fringes for climate resilience and sustainability;

12) Spatial planning to ensure short distances for commuting, errands and leisure;

13) Re-attributing urban space for mobility in favour of infrastructure for sustainable and active, zero-emission transport modes.

2.2.6. Integrated urban energy system

14) Positive Energy Districts;

15) Low and zero pollution heating and cooling systems to reduce air pollutant and greenhouse gas emissions.

2.2.7. Digitalisation and urban data platforms

16) Cross sector data interoperability for innovative AI services;

17) Support the sustainable digital transition of cities, overcoming social and digital divides;

18) Alleviation of energy and mobility poverty;

19) Enabling innovative, zero-emission goods delivery;

20) Enabling sustainable, zero-emission mobility, including multi-modality;

21) Inclusive decision making;

22) Digitally accessible smart cities.

2.2.8. Zero pollution cities

23) Air quality and climate-neutrality and their societal co-benefits.

24) Urban brownfields remediation

2.3. Empowering citizens to engage in the transformation to a decarbonised society

The activities envisaged under this section have a double purpose. On the one hand, they create opportunities for citizens – including those not represented by traditional stakeholder groups – to contribute insights, ideas and expertise on the climate and ecological transition and the transformation towards decarbonised societies and economies, thereby improving the societal relevance and impact of the resulting research and innovation actions. This also helps to mitigate inherent trade-offs and negotiate potentially diverging interests, addressing aspects related to justice, fairness and equity while equipping citizens with new knowledge, tools and skills, encouraging them to play an active role in the transition and to adopt more climate-conscious forms of behaviour. On the other hand, given that citizen engagement has obvious social, socioeconomic, cultural as well as governance-related implications, the activities in this section promote an interdisciplinary approach to climate, energy and mobility research and innovation, explicitly drawing on – and sometimes starting from – the social sciences and humanities (SSH), in addition to the scientific, technical, engineering and mathematical (STEM) disciplines.

The **main expected impacts** are[3]:

[3] Impacts listed here may be implemented within this part of the Destination and/or through integration in other thematic parts of the work programme.

Overarching impacts:

a) EU-funded research and innovation actions provide concrete, practical and durable opportunities for engaging citizens, ensuring that the resulting engagement is inclusive, deliberative and consequential;

b) EU citizens are equipped with greater climate-related knowledge, tools and skills and adopt more climate-conscious forms of behaviour;

c) EU research and innovation actions are more relevant to societal needs and therefore more impactful, drawing on citizens' insights, expectations, expertise and concrete involvement;

d) The different drivers and motivations facilitating or obstructing citizens' engagement, as well as the social, cultural, economic, and institutional settings in which such engagement takes place, are better understood, leading to improved policy outcomes;

e) Justice and equity implications of the EU's research and innovation support in the areas of climate, energy and mobility are better understood and reflected in EU policymaking, leading to better substantive outcomes;

f) SSH research and innovation communities in the fields of climate, energy and mobility are reinforced and better networked; their collaboration with corresponding communities in the STEM disciplines is strengthened; SSH disciplines are better integrated into the EU's research and innovation support.

Specific impacts:

g) Transition super-labs have been established as pilot actions and launched their first activities;

h) Conventional climate models have improved and take greater account of socio-economic variables;

i) EU research and innovation funding has contributed to building sustainable, decentralized energy systems in developing and emerging nations;

j) Land-use strategies and pathways are better understood, leading to improved policy outcomes by revealing limitations of inherent trade-offs;

k) EU communities and cities have become more sustainable, resilient, circular, inclusive, and gender-aware, leading to improved policy outcomes;

l) EU mobility patterns and their contribution to the health impacts of sedentary lifestyles are better understood, leading to improved policy outcomes;

m) Mobility systems and services in the EU have become smarter, rendering them more inclusive, safer and more sustainable, leading to improved connectivity and accessibility to transport services.

For achieving these impacts, topics are considered addressing the following **issues**[4]:

1. Land-use strategies and pathways;
2. Socio-technical approaches to climate-transition modelling;
3. Drivers and implications of citizens' engagement and their climate-, energy- and mobility-related behaviour;
4. Strengthening SSH-related research communities in climate, energy and mobility;
5. Accelerating the climate transition in especially difficult contexts: transition super-labs;
6. Strengthening climate, energy and transport justice;
7. Building sustainable, resilient, circular, inclusive, and gender-aware communities and cities;
8. Empowering citizens and consumers and developing their skills and knowledge;
9. Building sustainable, decentralized energy systems in developing and emerging nations;
10. EU mobility patterns and their contribution to the health impacts of sedentary lifestyles;
11. Developing smart, safe, accessible and sustainable mobility systems and services through mobility management, beyond urban areas.

2.4. Emerging breakthrough technologies and climate solutions

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

The development of breakthrough technologies 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.

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

[4] Issues listed here may be implemented within this part of the Destination and/or through integration in other thematic parts of the work programme.

approach and the support of key technologies that are expected to fuel decarbonisation. Research in this area is mostly technological in nature but could also 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:

a) Emergence of unanticipated technologies enabling emerging zero-greenhouse gas and negative emissions in energy and transport;

b) Development of high-risk/high return technologies to enable a transition to a net greenhouse gas neutral EU economy;

c) 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;

d) Advancement of methane cracking technologies for the decarbonisation of methane;

e) Establishment of novel inorganic photovoltaic absorbers using rapid development approach to lead to concepts that will improve the performance of photovoltaic technologies.

For achieving these impacts, topics are considered addressing the following **issues**[5]:

1. Technology-neutral bottom-up call for breakthrough climate technologies;
2. Direct atmospheric carbon capture and conversion;
3. Technologies for non-CO2 greenhouse gases recovery;
4. Methane cracking;
5. Novel solar energy harvesting materials and applications.

[5] Issues listed here may be implemented within this part of the Destination and/or through integration in other thematic parts of the work programme.

3. Destination 3 – Sustainable, secure and competitive energy supply

The transition of the energy system will rely on reducing the overall energy demand and decarbonising the energy supply side. R&I actions will 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 are needed to 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 decarbonised 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 impact

Activities under this Destination should set out a credible pathway for supporting a *"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"*.

This entails in particular:

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) Provide sustainable solutions for specific transport needs in aviation, shipping, or heavy duty road transport, for the heating/cooling sector, and in the heavy industry, within an overall circular economy concept in synergy with the bioeconomy.

c) 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.

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

3.1. Global leadership in renewable energy

The EU long-term climate strategy highlights the pivotal role of renewable energies in the future energy system and the achievement of the zero-emission target. Renewables provide also major opportunities to de-ffosilised other economic sectors such as heating/cooling, transportation and industry and their large scale and decentralised deployment will also improve the security of the energy supply and boost domestic jobs. Renewable energy technologies are the baseline on which to build a sustainable European future. A strong global European leadership in renewables will pave the way to increase energy security and reliability in time of crisis, as can be see today during the Covid crisis, to achieve the objectives of the European Green Deal and to sustain the economic recovery in the long term while ensuring a sustainable future for European citizens.

While efficiency improvements for the more established renewables, such as wind energy, photovoltaics or bioenergy, are envisaged, a further diversification of the technological portfolio is also needed to support the clean energy transition. Furthermore, renewable fuels, including synthetic and biofuels, provide long-term solutions for the transport and energy-intensive industry sectors, in particular for applications where fuels with high energy density or very large fuel quantities are required to reduce the carbon footprint of these sectors.

The focus is on the production of energy and of energy carriers. Renewable energy technology developments will be based on the principles of positive environmental impacts, of positive ratio of energy returned on energy invested (EROI) and of circularity. These principles will be applied in the development of the work programme.

The Clean Energy Transition partnership will cover partially some of the scope.

The **main expected impacts** are:

a) Advance the EU scientific basis, leadership and global role in the area of renewable energy and renewable fuels while creating evidence for policy making;

b) Provide breakthrough solutions towards a fossil-free economy and ecosystem;

c) Increase technology competitiveness, thus supporting the EU goals for climate protection, energy independence and economic growth;

d) Technology de-risk as a necessary step before scaling up at commercial level, thus facilitating achievement of net zero greenhouse gas emissions by 2030;

e) Facilitate market penetration of renewables and getting closer to the European Green Deal and climate and energy targets for 2030;

f) 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 fossil-free basis;

g) Enable the transformation of the energy supply to fossil-free across all energy-consuming sectors including energy intensive (iron and steel, chemical and petrochemical, non-ferrous metals, non-metallic minerals, and pulp and paper), light manufacturing, agriculture and transport;

h) Enhance sustainability of renewable energy and fuel value chains by addressing social, economic and environmental aspects in full, thus ensuring the European Grean Deal priorities are met;

i) Reinforce the EU scientific basis through international collaboration while increasing the potential to export EU renewable energy technologies and ensuring political priorities.

For achieving these impacts, topics are considered addressing the following **issues** grouped under eight sub-headings:

3.1.1. Novel renewable energy technologies

Development of disruptive renewable energy and fuel technologies and systems for existing and new applications (bring TRL up to 4)

1) Bottom up development of breakthrough renewable energy techlologies (conversion tehnologies and use of technologies);

2) Direct sunlight direction to solar fuels;

3) Hybrid catalytic conversion of renewable energy to carbon-neutral fuels;

4) Micro-scale solar-cell arrays with integrated concentration- micro-CPV.

3.1.2. Cost reduction and efficiency improvement of renewable energy technologies

Improvement of cost and efficiency of renewable energy and fuel technologies and their value chains (TRL 4-5)

5) Wind: Physics and aerodynamics of atmospheric flow of wind for power production; Integrated wind farm control; Wind energy in the natural and social environment;

6) Solar PV: Novel tandem, high efficiency technologies targeting low cost production with earth abundant materials; Novel Thin Film (TF) technologies targeting high efficiencies; Stable high performance Perovskites;

7) Bioenergy: Cost-effective micro-CHP and hybrid heating systems; Efficient and low-emission technologies for industrial use of combustion and gasification systems from low-value biogenic residues and wastes; Carbon fixation and gas cleaning technologies for biogenic flue gases from heating;

8) Biofuels and alternative renewable fuels: Development and co-processing of bioenergy carriers in oil refineries; Development of algal and renewable fuels of non-biological origin; Carbon-negative biofuel production;

9) Solar CSP: Novel CSP cycles; Thermal energy storage for CSP plants and other uses;

10) Geothermal: Innovative concepts for prediction and assessment of geothermal resources; Solutions for more sustainable geothermal energy; New technologies for geothermal well completion, operation and monitoring;

11) Ocean: Improvement of tidal blades and rotor; Innovative circular materials for innovative foundations, floating substructures and connection systems for floating or bottom-fixed ocean energy devices; Improvement of the environmental and socioeconomic impacts of ocean energy;

12) Hydropower: Development of hydropower equipment for improving techno-economic efficiency and equipment resilience in refurbishment situations; Development of hydropower equipment for hidden hydropower; Development of digital solutions for existing hydropower operation and maintenance.

3.1.3. <u>Scale up renewable energy technologies</u>

Demonstration of renewable energy and fuel technologies (TRL 5-7)

13) Wind: Blade recycling; Innovation on floating wind energy deployment; Coupling off-grid wind energy with power-to-X;

14) Solar PV: Advanced manufacturing of integrated PV; Novel c-Si tandem demonstration pilot lines; Recycling end of life PV modules;

15) Bioenergy: Retrofitting of large-scale CHP to the use of biogenic residue, Intermediate bioenergy carrier production by phytoremediation from polluted lands and landfills; Innovative renewable energy carrier production for heating from renewable energies;

16) Biofuels and alternative renewable fuels: Retrofitting industrial plants for biofuel production; Innovative biomethane production as an energy carrier and a fuel; Demonstration of complete value chains for biofuel and non-biological renewable fuel production.

17) Solar CSP: Innovative components for CSP plants; Thermochemical storage for CSP;

18) Geothermal: Demonstration of zero emissions power plant; Demonstration of large geothermal plants (>5 MW) for heating and electricity generation from unconventional resources; Demonstrate the use of high temperature geothermal reservoirs to provide energy storage for the energy system;

19) Ocean: Demonstration of innovations for tidal turbine technology development; Demonstration of wave energy devices to increase experience in real sea conditions;

Demonstration of innovative condition monitoring systems for tidal energy devices to increase experience in real sea conditions;

20) Hydropower: Demonstration of sustainable hydropower refurbishment, innovative pumped storage equipment and tools; Demonstration of hydropower at hidden hydropower opportunities.

3.1.4. Market up-take of renewable energy technologies

21) Bottom up market up-take measures of renewable energy and fuel technologies[6].

3.1.5. Flexible and integrated renewable energy solutions

Development of renewable energy and fuel-based solutions combining variable with dispatchable technologies and integrate them efficiently within the existing energy system infrastructure (TRL 4-7)

22) Demonstration of Virtual Power Plant (TRL 5-7) targeting dedicated technologies allowing an easy integration of diverse renewable energy source generation system into a seamless energy production installation;

23) Retrofitting existing power, heating or combined heat and power generation stations through develop hybrid combined heat and power-generation systems integrating several and different renewable energy technologies in hybrid power, heating or CHP units (TRL 4-5);

24) Retrofitting existing fuel refineries to polygeneration energy systems integrated in the refineries to deliver electricity, heat, refrigeration and fuels from combined renewable energy resources and technologies (TRL 4-5);

25) Demonstration of micro-algae biofuel technologies in hybrids with renewable electricity generation integrated in biomass based industrial CHP, waste treatment, anaerobic digestion or biomass fermentation plants by using BECCS for process CO2 and renewable electricity for process hydrogen (TRL 5-7);

26) 100% renewable heating, cooling and power in building (TRL 5-7);

27) Combine renewable energies to solar fuels through developing technological interfaces for efficient and continuous renewable fuel production (TRL 4-5);

28) Autonomous and local renewable energy systems: innovative plug-and play solutions for system management and renewables storage in off-grid applications (TRL 5-7).

3.1.6. Embed renewable energy technologies in energy consuming sectors

Development of solutions for embeded renewable energy and fuel technologies in the transport, agriculture, chemical, manufacturing and energy-intensive industrial sectors (TRL 4-7)

[6] While the focus will be on renewable energy technologies, it will be complementary to the programme LIFE.

29) Renewable energy carriers from variable renewable electricity surplus and carbon emissions from energy consuming sectors (TRL 5-7);

30) Renewable energy incorporation in intensive manufacturing/chemical /petrochemical industry for high-temperature heat demand combining several renewable technologies (TRL 5-7);

31) Renewable energy incorporation in SME manufacturing industry for low- to medium-temperature heat demand combining several renewable technologies (TRL 5-7);

32) Renewable energy beyond electricity incorporation in chemical industry processing, e.g. electrochemical potential of artificial photosynthesis to chemical reduction processes (TRL 4-5);

33) Renewable energy incorporation in fossil fuel production integrating macro-algae full pathways (TRL 5-7); Vehicle-integrated Photovoltaics (VIPV) as a core source for electricity in road transport;

34) Renewable energy incorporation in agriculture to meet its electricity, heat and waste management needs, by also transforming in situ agricultural wastes to renewable energy carriers and combining different renewable regional value chains and adapted storage options to decarbonise agricultural processes trans-seasonally (TRL 5-7); Novel Agro-Photovoltaic systems (TRL 5-7).

3.1.7. Sustainability

35) Bottom up development of sustainable solutions for renewable energy and fuel technologies encompassing circularity by design, life cycle assessment of the entire value chain including materials, external costs, synergies and public acceptance. Development of human capital through education and training. This aims to address methodology development for RES value chains when these are scaled up and/or combined in variable and flexible RES systems.

3.1.8. International Cooperation

36) International cooperation focusing on Mission Innovation countries: Digital solutions for defining synergies in international renewable energy value chains; Best-practice for scaling up sustainable fuels;

A dedicated set of actions is foreseen for the implementation of the present R&I Partnership on Climate Change and Sustainable Energy of the EU/AU High-Level Policy Dialogue on Science, Technology and Innovation, which is expected to strongly contribute to Action 1 of the Comprehensive Strategy with Africa (TRL 3-5).

37) EU-Africa – Water-Energy-Food-Nexus through decision assisting modelling to implement energy infrastructures and energy supply in Africa;

38) EU-Africa – Energy System Modelling through decision making modelling and increasing African expertise for the development of a renewable based energy system;

39) EU-Africa – Demonstration of RES technologies at scale in real African settings;

40) EU-Africa – R&I Joint Programme establishing the next steps for a deeper collaboration between EU and Africa in the development of sustaineble energy system.

3.2. Energy systems, grids and storage

Decarbonisation, cost-effectiveness and affordability, security of supply and grid stability as well as other objectives of the clean energy transformation depend on an efficient and effective network management and optimisation, leading to increased demand response and the ability to integrate higher shares of variable renewable energy and to appropriately monitor their availability (at all voltage levels). Exploiting synergies between different electricity, heating and cooling networks, gas networks, transport infrastructure and digital infrastructure will be crucial for enabling the smart, integrated, flexible and green operation of the relevant infrastructures. Capturing excess electricity and heat to use it at a later point in time is an essential requirement for the cost-effective and secure transition of the energy system towards decarbonisation. Electrochemical, chemical, mechanical, electrical and thermal storage solutions will increase the flexibility of energy systems, which requires strong investments in research and innovation to complement areas of batteries and hydrogen. 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 the areas of batteries, hydrogen and RES. Precisely, the Energy Systems, grids and storage area will primarily focus on the systemic aspects, including integration of renewables and all storage solutions in the energy system. Batteries and hydrogen are the focus of the relevant sub-areas 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 on the RES sub-area.

The **main expected impacts** are:

a) Better system controllability, higher network efficiency and cost-effectiveness;

b) Increased integration of variable renewables;

c) Increased resilience of the energy system - ability of society to continue activities with critical loads in situations of emergency and partial failure. Increased RES penetration without undermining system stability. Increased energy security and reduced effects of major catastrophic events.

d) Demonstrated sector coupling capabilities to increase energy resilience and constribution to complete decarbonisation of the energy sector and well as a finalised

assessment on the possible quantitative contribution of sector coupling and cost reductions for related energy technologies and processes;

e) Better and more efficient energy system planning leading to maximal cost-efficency for grids upgrading, matched by full exploitation of the potential of local flexibility options or new local storage facilities as an alternative to building new lines and the identification of cost-effective solutions to avoid overinvestment;

f) Better and more efficient operation of smart grids (electricity and gas), while fully guaranteeing their security, reliability, market-compatibility and resilience;

g) Enabled new market roles, market participants and energy communities, successfully mobilising demand-response and contributing to increased level of flexibility and to the development of new flexibility products;

h) Higher degree of interoperability among players, enabling new digital solutions and services supporting the energy transition. System-wide implementation of new energy services and business models as well as tested standardised interfaces of energy IoT devices;

i) Demonstated hybrid Alternate Current – Direct Current grid solutions as well as MT VSC-HVDC (Multi Terminal Voltage Source Converter - High Voltage Direct Current) solutions for transporting off-shore energy.

For achieving these impacts, topics are considered addressing the following **issues**:

3.2.1. Energy Sector Integration

1. Integrating and combining power, heat, gas and other sectors (industry and mobility) to a cost-optimised, flexible energy system of systems with massively integrated RES;

2. Enhance energy system flexibiliy, through coupling of electricity with other energy vectors such as gas, heat and cooling, liquids as well as with the other sectors (mobility/transport, buildings and industry);

3. Identification of barriers and the role of grid operators (effective integration of improved technologies such as higher efficiency electrolysers, optimisation of interfaces between energy systems, development of new technologies for power-to-liquids).

3.2.2. Energy system planning and operation

4. Development of innovative grid planning tools and solutions;

5. Development of effective solutions to support operators in making the best use of network capacity while optimally integrating Distributed Energy Resources and minimizing costs;

6. Optimisation of electricty and gas synergetic grid development combining market analysis, production capacities, distributed generation and demand-response capacities, considering also infrastructure, storage and environmental constraints;

7. Development of new methods to take into accounts new types of assets connected to the grids (Electric transport , storage, small scale production, non-synchronous generators, etc.);

8. Integration of digital technologies (Artificial Intelligence, Big Data), solutions and platforms into the operation of the energy system, taking into account interoperability requirement and data sharing.

3.2.3. Storage development and integration

9. Development, succesful operation and integration into the energy system of innovative storage solutions (chemical, electrical, thermal, mechanical) to enable and drive further the succesful penetration of renewable into the energy mix across several sectors (industry, energy, transport, residential, agriculture);

10. Interoperable solutions for flexibility services using distributed energy storage.

3.2.4. Pan-European transmission of energy

11. Demonstration of extensive hybrid Pan-European AC-DC grid control as well as of offshore grids for transporting off-shore RES energy. Development and application of efficient technologies to bring large amount of energy to the mainland loads.

12. Testing and demonstation of new grid architectures based on DC technologies on different voltage level, avoiding double DC/AC/DC conversion. Development of the relevant powerelectronics (including components).

13. Assessment of the potential of European level long distance electricity transmission as alternative to storage.

3.2.5. Green digitalisation of the energy system - Interoperability and data

14. Incresed interoperability and access/sharing of data of the digital energy infrastructure (including among others Internet of Things devices, Smart Meters, Energy Smart elements (i.e. Energy Smart Appliances, batteries ...), all type of platforms, Home Energy Management System (HEMS), Building Energy Management System (BEMS), interfaces for the exchange of information (i.e. Application Programme Interfaces-APIs), interoperable open standards, Digital Twins (and the development of data driven services/solutions on top of them) and AI algorithms at different levels, exploiting advances in Distributed Ledger Technology (DLT), integrating ICT tools (hardware and software) at the grid edge level enabling real-time response.

15. Adoption of a variety of action enabling the successful Digitalisation of the Energy Systems, for example adapting digital technologies to the specificities and requirements

of the Energy system (AI, Big Data, 5G, cloud/edge computing, IoT ...) and developing innovative solutions to make energy data available (i.e. through the deployment of an European Data Space for Energy) as well as a European community of knowledge at the intersection of Digital & Energy.

3.2.6. Active consumers, Markets and Energy Communities

16. Optimal engagement of distributed active consumers and energy communities, reconciling the top-down market/system developments with bottom-up changes in the market arrangement and participation;

17. Developing and testing incentives for market participants to react to system conditions according to location and time as well as developing the entire fuctional chain from data collection and elaboration, to local flexibility needs and user-centric compensation enabling the active partcipation of prosumers.

3.2.7. Electricity system reliability and resilience

18. Increasing the reliability and resilience of the electricity system, taking into account risks associated to extreme natural events, man-made threats (including cyber-threats) and crisis scenarios;

19. Development and testing of strategies, technologies, tools and approaches to enhance the level of reliability and resilience on the baisis of new infrastructure design, new electrical components, new system operation and maintenance taking into account strict data privacy and cyber-security requirements.

3.3. Carbon capture, utilisation and storage (CCUS)

CCUS will play a crucial role in the EU Green Deal for the decarbonisation of energy-intensive industries and the power sector by supporting R&I for these solutions. CCUS will be particularly important in those industries where other alternatives do not 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 even create negative emissions.

Clean hydrogen from natural gas with CCUS could also play a significant role in industrial decarbonisation in the transition towards full use of green hydrogen, 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 green hydrogen. It is thus important to develop CCUS for industrial clusters, including aspects of system planning, shared infrastructure solutions such as buffer storage, shared CO2 and green/clean 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 CO2 transport is needed. Solutions for the conversion of captured CO2 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 CO2 storage appraisal, cost-reductions, new technologies and proliferation of pilots and demonstrators.

The **main expected impacts** are:

a) Accelerate rollout of infrastructure for CCUS hubs and clusters;

b) Update authoritative body of knowledge on connecting industrial CO2 sources with potential bankable storage sites, providing greater confidence for decision makers and investors;

c) Prove 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.

d) Reduce cost of carbon capture, which is still the most relevant stumbling block for a wider application of CCUS.

For achieving these impacts, topics are considered addressing the following **issues**:

1. Integration of CCUS in hubs and clusters, including knowledge sharing activities;
2. CO2 transport and storage demo projects, feasibility studies;
3. Decarbonising industry (steel, cement, waste incineration, refineries, chemical industry, hydrogen production, ...) with CCS/CCUS;
4. Cost reduction of CO2 capture (new or improved technologies, through integration in existing facilities);
5. Developing and monitoring new storage pilots with particular consideration of safety aspects and public engagement on CO2 storage and transport.

3.4. Cross-cutting issues

Clean Energy Transition Partnership

The Clean Energy Transition Partnership (CETP) aims to empower the energy transition and realise the EU's goal of becoming the first climate-neutral continent by 2050. To achieve this

ambitious goal, Europe needs to launch 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 can be turned into an opportunity for sustainable growth and competitiveness, creating high-quality jobs and leaving nobody behind.

The CETP will work to overcome the challenges via a joint, shared, transnational approach, engaging a wide variety of stakeholders including industry and research institutes. It aims 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 implementation across Europe as needed.

The **main expected impacts** are:

a) Pooling and efficient use of national and regional resources/funding programmes.

b) Enabling 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.

c) Better cost performance by improving sustainability and reliability of a broad portfolio of clean energy technologies and solutions;

d) Integration of many new energy solutions and 'first of a kind' technologies on all levels of the energy system to give flexibility and to cope with self-generation and consumption profiles by new holistic solutions for energy storage, storage of surplus energy to provide peak load supply security and inter-seasonal energy storage techniques;

e) Engagement of consumers and prosumers in appropriate demand-response mechanisms and its integration in the energy system;

f) A resource-efficient energy system, both from an ecological and economic standpoint, considering a broad perspective on sustainability and resource efficiency;

g) An energy system that meets the needs of different parts of society, in different geographical locations (urban and rural) and different groups;

h) A zero-emission energy system for the decarbonisation of mobility, buildings, industry, agriculture in a specific environment;

i) Acceleration of the sustainable energy transition and societal development by the use of opportunities arising from the digital transformation.

The Clean Energy Transition Partnership will address the following **activities**:

1. Development of clean and affordable energy production and conversion technologies.
2. Development of a climate neutral, flexible and robust energy system;
3. Storage and its integration in the energy system;
4. Resource and energy efficiency and circular flows in the energy sector for an ecologically sustainable energy system;
5. A just and inclusive energy transition;
6. Sector integration and coupling;
7. Digital transformation.

4. Destination 4 – Efficient, sustainable and inclusive energy use

Research and innovation actions aiming at fostering demand side solutions and improving energy efficiency are among the most cost effective ways to support decarbonisation, 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 decarbonised energy system will greatly benefit from the use of digital technologies which will enable **buildings** and **industrial facilities** to become interactive 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.

Expected impact

Activities under this Destination should set out a credible pathway for *"Efficient and sustainable use of energy, accessible for all is ensured through a clean energy system and a just transition"*.

This entails in particular:

a) Delivering the technology and socio-economic breakthroughs necessary to achieve the full decarbonisation of the building stock by 2050 through energy efficiency, renewables, digitalisation and smart operation of buildings, bearing in mind user needs and the need to move towards climate neutrality in the longer term as well as to limit whole life carbon as well as other life-cycle environmental impacts of buildings.

b) Enable the transition to carbon-neutrality and the competitiveness of industry, through the integration of renewable and low-carbon energy sources and the optimisation of the enhanced energy system, in order to minimise the total investment and operation cost, hence satisfying the future final uses of energy (and feedstock) of industry at lowest cost.

4.1. Highly energy-efficient and decarbonised EU building stock

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.

This intervention area 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 implemented through traditional calls for proposals as part of this cluster. 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 to develop holistic R&I for an effective transition to sustainability. The actions implemented under the partnership will be bigger in scope and size than the traditionall calls and will rely on a coordinated approach between a broad range of players and policy areas.

The **main expected impacts** are:

Regarding the activities implemented through the traditional calls:

a) Deep energy buildings renovations: Increased rate of buildings renovation through industrialised desgin and process improvements, including district-scale approaches, leading to savings in costs and in time spent on site

b) Higher quality construction and improved compliance: Reduction towards zero in the gap betwen calculated and measured energy performance

c) Energy efficiency improvements in the operation of buildings: Improved energy performance and better monitoring and assessment using smart technologies and related data

d) Innovative energy performance calculation methods: Increased uptake and convergence of energy performance calculation and certification methods, and compliance with EU Directives and related standards

Regarding the activities implemented under the Partnership:

a) Decarbonisation, clean energy and mobility: Contribution of the built environment for enabling a smarter, more decentralised and flexible energy system based on more efficient energy use and renewable energy generation, and to the decarbonisation of the transport sector by supporting clean mobility.

b) Resources efficiency and circularity: Transition from a linear to a circular economy in buildings and construction andincreased resource efficiency in the built environment.

c) Water & Biodiversity: Symbiotic operation of buildings/infrastructure with natural environment

d) Resilience: Reduction in built environment exposed to physical risks from changing climate.

e) Value and competitiveness:

- Increased competitiveness of the EU construction industry and real estate sector.
- Increased long-term value, profitability, sustainability and overall investments performance and investor confidence.

f) Health and wellbeing: Improved built environment leading to a better quality of living for people as citizens and economic actors.

g) Just transition and social values:

- Reduced costs of the transition for citizens by ensuring the affordability of new and renovated building stock.
- Affordable and accessible buildings ensuring adequate warmth, cooling, lighting for guaranteeing health and a decent standard of living for all.
- Respectful approach to the built environment, including heritage, spatial design and natural landscapes to preserve European identity.
- Enhanced citizen's engagement, empowerment, participation and co creation.

For achieving these impacts, topics are considered addressing the following **issues**:

Issues implemented through the Partnership are not yet included.

1. Industrialisation of deep energy renovation workflows
1. Whole life cycle NZEB digital twins
2. Smarter buildings for better energy performance
3. Automated and robotic construction for energy efficient buildings
4. Advanced energy performance data in buildings
5. Future-proofing historical buildings for the clean energy transition
6. Demand response in energy-efficient residential buildings
7. District approaches to industrialised energy renovation
8. Energy positive homes
9. Advanced energy performance assessment and certification

4.2. Industrial facilities in the energy transition

The **main expected impacts** are:

a) Optimised and upgraded energy system that satisfies the energy needs of industrial clusters and/or industrial macroregions at lowest cost whilst contributing to the Green Deal objectives including circularity and zero pollution ambition.

b) Increased energy efficiency and reduced GHG-emissions through recovery, upgrade and/or conversion of industrial excess (waste) heat.

For achieving these impacts, topics are considered addressing the following **issues**:

1. Develop and validate cost and performance models of the components of the energy system, integrate these component models into an energy system model, thereby providing a planning tool for optimising the enhanced energy system.

2. Develop and improve technologies to use industrial waste energy (heat, cold …), by recovering, upgrading and/or converting to other energy vectors.

5. Destination 5 – Clean and competitive solutions for all 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 partnerships and are therefore not included in this document.

Expected impact

Activities under this Destination should set out a credible pathway *"Towards climate-neutral and environmental friendly mobility through clean solutions across all transport modes while increasing global competitiveness of the EU transport sector"*.

This entails in particular:

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 decarbonisation transformation, 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.

5.1. Zero-emission road transport

The mobility of people and goods is the lifeblood of an integrated European single market, territorial cohesion, and an open and 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 performances. 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 to accelerate the development of a zero tailpipe emission transport in Europe with a system approach, and will develop a common vision and deliver a multi-stakeholders roadmap for a climate neutral and clean road transport system. It will improve mobility and the 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 and more liveable urban, peri-urban spaces. Further, major benefits for citizens' health, quality of life will be generated and European economic growth supported, hence a solid base for new business opportunities. 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 CO2 and other GHG emissions will contribute to mitigating climate change.

Several levels of interactions are foreseen with other European initiatives, in particular with Batteries, Clean Hydrogen, Cooperative Connected and Automated Mobility (CCAM), Key Digital Technologies, and Driving Urban Transition (DUT) partnerships, as well as with the mission on Climate neutral and smart cities.

The **main expected impacts** are:

a) Accelerated zero tailpipe emission, affordable user-centric solutions (technologies and services) for road-based mobility all across Europe and users acceptance to improve air quality in urban areas and beyond;

b) Reduced non-powertrain related emissions and transport related noise;

c) Affordable, user-friendly charging infrastructure concepts and technologies that include vehicle and grid interaction;

d) Demonstration of innovative use cases for the integration of zero tailpipe emission vehicles and infrastructure concepts for the road mobility of people and goods;

e) Life-cycle analysis tools and skills for the effective design, assessment and deployment of innovative concepts in products/services in a circular economy context.

For achieving these impacts, topics are considered addressing the following **issues**:

1. Vehicle technologies and vehicle propulsion solutions for zero-emission vehicles (Battery Electric Vehicles and Fuel Cells Electric Vehicles);

2. Integration of Electric Vehicles into the energy system and related charging infrastructure;

3. Innovative concepts and services for the zero emission mobility of people and goods;

4. Life Cycle Analysis approaches and Circular Economy aspects for sustainable and innovative road mobility solutions.

5.2. Rail

Under Horizon Europe, the institutionalised Partnership on Transforming Europe's rail system will deliver on an integrated and sustainable rail system, based on a vision shared by the sector towards improved operational reliability, robustness and efficiency. The work on defining the programme of the future partnership is ongoing. Attention will be payed to coordinate the R&I activities under the Partnership with the activities included in the Work Programmes under Horizon Europe.

5.3. Aviation

Aviation, climate and 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 €700 billion per year. The European economic benefit from aviation contributes to European prosperity, allows EU leaders to absorb external shocks (e.g. financial crisis, COVID-19) and invest in climate neutrality and social 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 CO2 emissions and shorter-term ones (several hours, days, weeks or years) from non-CO2 emissions (mainly from water, NOx, SOx, soot, contrails and contrail cirrus). The CO2 effects are well understood and are proportional to the fuel used. The non-CO2 effects are still poorly understood and carry large uncertainties. The total impact of global aviation to Green House Gas (GHG) emissions in 2005 (the most recent complete and reliable available measurements) was estimated to represent 4.9% of total anthropogenic forcing, where 1.6% was attributed to CO2 and 3.3% was attributed to non-CO2 emissions. Until ultra-clean transformative aircraft propulsion will revolutionise aviation, energy efficiency and increased aircraft performance remains one of the main priorities. Over 10 billion tonnes of CO2 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 two streams of activities:

1. A European Clean Aviation Partnership (EPCA) focused on high-TRL (4-6) and three clearly identified paths, as described in SRIA (which is under public consultation until the

11/06). It should aim towards accelerating the development, integration and validation of climate-neutral aviation technologies 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, 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 think-tanks (e.g. ASD, ACARE, EUROMART, 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.

Further alignment between the two streams will be performed following the finalisation of SRIA.

The **main expected impacts** are:

a) Disruptive gains by 2035, with upto 30% reduction in fuel burn and CO2 between the existing aircraft in service and the next generation, compared to 12-15% in previous replacement cycles;

b) 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;

c) New technologies for significantly lower local air-pollution and noise;

d) Support recovery from the COVID crisis and 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;

e) Protect the passenger and increase the resilience of the aviation ecosystem to external shocks (e.g. health issues, manufacturing, operations, cybersecurity);

f) 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.

For achieving these impacts, topics are considered addressing the following **issues**:

5.3.1. Climate-Neutral Aviation (TRL 1-4)

5. New aircraft and engine technologies for ultra-low emissions and noise (e.g. new configurations, optimised aircraft-propulsion interaction, new metallic, composite and multifunctional aerostructures, advanced life prediction methodologies, flow control, high-lift aerodynamics, aeroacoustics, control systems)

6. New enabling technologies that will contribute to a generic 50-70 pax Regional Hybrid-Electric aircraft by 2035

7. New technologies that satisfy the design and operational interdependencies between CO2, non-CO2 and noise emissions

8. Aviation emissions - assessments and measurements for policy (aircraft technologies & operations)

5.3.2. Digitalisation and competitiveness (TRL 1-4)

9. Digital Aircraft - from design and manufacturing to operations and recycling

10. Enabling technologies for new aircraft business models & services – EGNSS based Search & Rescue, UAV swarms, UAM, seaplanes, firefighting, High Altitude, cargo

11. New technologies for game-changing health and performance sensing & MRO

12. Digital-physical scaled demonstrator aircrafts for education, research and development

13. Digital Factory - from aircraft components to Final Assembly Line (FAL).

14. Impact of extreme weather phenomena and emerging global threats to aviation

5.3.3. Support European Aviation Research Policy

15. EU policy-driven planning and assessment framework/toolbox

16. Communicate the EU aviation R&I to citizens and stakeholders

17. Strengthen ERA in Aviation R&I and promote aeronautics/aerospace spin-offs in all aspects of life.

18. Connect Aviation R&I with education and skills

5.4. Enabling, low-carbon, clean, smart, and competitive waterborne transport

The European Green deal refers to the need to achieve clean, carbon neutral shipping and to the importance of innovation in this respect. Within the International Maritime Organisation, global agreement was reached in 2018 to cut total shipping GHG emissions by at least 50% by 2050 compared to 2008. The EU is even more ambitious and by the same date aims to cut all transport emissions by at least 90%. To provide the essential innovation needed to achieve these targets, a new focussed "Zero Emission Waterborne Transport" co-programmed partnership is

proposed which will mobilise resources towards the central objective of demonstrating by 2030 the deployable solutions needed for all main types of waterborne transport to become zero emission by 2050. In addition the competitiveness of European waterborne industries, smart ports and the increased use of inland waterway and coastal transport in low carbon logistic will be enabled both through green solutions developed within the partnership and by developing automation and digital technology to revolutionize inland and maritime operations, enable new business models, exploit new markets, increase production and operational efficiency, and improve security. Actions will also support resilience and recovery post COVID which has particularly impacted the passenger shipping sector which is critical for the European waterborne industry.

The **main expected impacts** are:

a) Increased deployment of climate neutral fuels and electrification of shipping;

b) Increased energy efficiency and lower fuel consumption (important for more expensive alternate fuels);

c) Enable the innovative port infrastructure (bunkering of alternative fuels and electricity) needed to achieve zero-emission waterborne transport (inland and maritime);

d) Enable clean, climate-neutral, climate-resilient inland waterway vessels before 2030;

e) Substantially reduce environmental impact of shipping (e.g.: biodiversity, noise, pollution and waste);

f) Towards achieving climate neutrality, eliminate harmful pollution to air and water;

g) Achieve smart efficient, safe, integration of marine and inland shipping into logistic chains, facilitated by digitalisation and automation;

h) Climate resilient waterway and port infrastructure;

i) Competitive waterborne industries supporting jobs and growth in Europe;

j) Enable fully automated shipping (maritime and inland) and efficient connectivity.

For achieving these impacts, topics are considered addressing the following **issues**:

5.4.1. Zero Emission Waterborne Transport (Partnership)

1. Enabling the safe efficient on board storage and integration within ships of large quantities of ammonia and hydrogen fuels;

2. Enabling deployment in shipping of low flash point GHG neutral fuels by ensuring safety underpinned by the necessary norms and regulations;

3. Enabling the full integration of very high power fuel cells in ship design using combined cycles for increased efficiency with multiple fuels;

4. Ensuring clean efficient engines using new carbon neutral fuels separately and in combination;
5. Exploiting the potential of innovative electrical energy storage systems and how to better optimise large battery electric power within fully battery electric and hybrid ships;
6. Hyper powered fast charging of battery vessels;
7. Exploiting renewable energies, particularly wind assistance for ships;
8. Energy saving technology to improve efficiency;
9. Refits to cut GHG's and pollution from existing vessels;
10. Assessing and preventing methane slip form LNG engines in all conditions within both existing and new vessels;
11. Sensorisation, data merging and digital twin modelling to improve efficiency, and increase owner confidence in innovative green system performance;
12. Proving the feasibility and safety of a large clean ammonia engine.

5.4.2. Automated and Connected Waterborne Transport

13. Seamless safe logistics through a fully automated and connected Waterborne freight feeder service;

5.4.3. Competitiveness of Waterborne Industries

14. Advanced Computational tools for ship building

5.5. Impact of transport on environment and human health

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. Noise pollution from railways remains one of the main barriers for expanding their use in urban areas and along densely populated rail freight corridors; and aircraft noise is often the reason for the difficulty of expanding airport capacity at major European hubs. 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 road vehicles and railway rolling stock (for both locomotives and freight wagons)

For achieving these impacts, topics are considered addressing the following **issues**:

1. Affordable solutions for reducing existing vehicle fleet polluting emissions and adaptable measurement tools for emissions;
2. Development and deployment of systems for reducing noise and other types of emissions (brakes, tyres) from the automotive fleets
3. Development of low solutions for quieter rail freight wagons (achieving a reduction of at least 6dB(A) compared to current limits);
4. Prevent smog episodes in Europe: mitigate particle formation and study of the precursors from transport;
5. Monitoring of toxic emissions, noise, and vehicle tempering on roads, ports, and airports.

6. Destination 6 – Safe Resilient Transport 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 impact

Activities under this Destination should set out a credible pathway towards *"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"*.

This entails in particular:

a) Decrease number of transport accidents, incidents and fatalities.

b) Increase the resilience of transport systems.

c) Accelerate the implementation of innovative connected, cooperative and automated mobility (CCAM) technologies and systems for passengers and goods to increase safety, inclusiveness and reduce environmental impacts.

d) 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, and optimised system-wide network efficiency and resilience.

6.1. 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. The focus is on road transport, but relevant interfaces with other modes (for instance transfers and integration with public 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 and the acceptance of these solutions by the users and society. The development of innovative technologies for connected and automated vehicles, the validation of all aspects of the CCAM system and 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.

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 **main expected impacts** are:

a) Accelerated uptake of innovative inclusive, user-oriented and well-integrated mobility and logistics concepts for passengers and freight enabled by CCAM;

b) Safe and efficient functioning of automated driving systems on public roads;

c) Validated functional safety for CCAM technologies and systems;

d) Reduced transport emissions and congestion by increased efficiency of transport flows (people and goods) and better use of infrastructure capacity;

e) Affordable and user-oriented mobility and goods delivery services for all;

f) High public acceptance and adoption of CCAM with clear understanding of its benefits and limits;

g) European leadership in the development and deployment of connected and automated mobility and logistics services and systems, ensuring long-term growth and jobs.

For achieving these impacts, topics are considered addressing the following **issues**:

1. Large-scale demonstration of integrated shared automated mobility and freight delivery solutions;

2. Development of technologies which enable the vehicle to perceive the environment, take decisions, ensure a secure and trustworthy interaction with the users, other traffic

participants, infrastructure and services, provide protection in case of emergency and improve the robustness and resilience of CCAM systems and services;

3. Validation of all aspects of the CCAM system;

4. Integration of the CCAM vehicle in the transport system (interaction with transport users/means, the environment and infrastructure, comprising road and telecommunication infrastructure as well as automotive backend infrastructure);

5. Societal needs, socio-economic and environmental impact, and user acceptance;

6. Coordination and cooperation of R&I and testing activities across Europe.

6.2. Multimodal and sustainable transport systems

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 for the decarbonisation and digitalisation of mobility and transport. 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, green and smart multimodal logistics are key for seamless and efficient long-haul and urban freight transport movements. Finally, optimised and 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:

a) Upgraded and resilient physical and digital infrastructure for clean, connected and automated multimodal mobility;

b) Sustainable and smart long-haul and urban freight transport and logistics, through increased efficiency and improved interconnectivity;

c) Diminished negative externalities (e.g. congestion, air and noise pollution and road collisions) of urban and peri-urban transportation;

d) Enhanced local and/or regional capacity for governance and innovation in urban mobility and logistics;

e) Reduced congestion, traffic jams and emissions as well as optimised system-wide network efficiency and resilience.

For achieving these impacts, topics are considered addressing the following **issues**:

6.2.1. Infrastructures

1. Adapting transport infrastructures to new vehicles, mobility needs and patterns, in order to enable efficient mobility and improve safety levels;
2. Design, upgrade and maintenance of transport infrastructure, demonstrating resilience to extreme weather events;
3. Construction of new/green transport infrastructures and decommissioning of ageing/grey infrastructures with zero emission effects;
4. Innovative solutions to ensure navigability of inland waterways and strengthen the modal shift to inland waterway transport, while protecting its ecosystems and habitats.

6.2.2. Freight transport and logistics

5. Improving efficiency of multimodal freight nodes (ports, terminals) to increase flexibility, service visibility and reduce the average cost of freight transport;
6. Logistic system integration and harmonisation through operational connectivity to optimise freight flows;
7. Resilient secure data integration and connectivity for shipping in enhanced logistics, including legacy systems, waterways, vessels and ports;
8. New concepts and approaches for resilient logistics networks against disruptive events (including pandemics), securing continuity of freight transport and minimised negative impacts;
9. Social innovation to changing consumers' and sellers' behaviours towards greener freight delivery choices, on the basis of advanced information on delivery-related emissions and alternative delivery solutions;
10. New delivery methods to optimise and offer green last mile deliveries in a variety of urban environments, reduce related emissions and congestion in cities;
11. New solutions and business models for space management in cities to optimise land use and logistics flows;
12. Developing urban freight transport data collection, to boost integrated urban mobility systems and support cities' decision making processes to achieve sustainability targets;
13. Strategic Sustainable Urban Mobility Planning[7] (SUMP) logistics integration to achieve effective TEN-T functioning by addressing urban node bottlenecks through local and regional coordination.

6.2.3. Network and Traffic Management

14. Design and validation of multimodal, dynamic, (cyber-)secure and resilient transport network and traffic management systems;

[7] https://www.eltis.org/

15. Harnessing data from the entire transport network to develop integrated data management systems, for effective multimodal network and traffic management and system-wide optimisation of transport demand/capacity balancing;

16. Developing new governance models and defining roles for public and private stakeholders in transport network and traffic management functions.

6.3. Safety and resilience - per mode and across all transport modes

Safety and resilience are of primary concern for any transport system. The EU set ambitious targets in its 2011 Transport White Paper. 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 (e.g. train stations, airports, and ports), 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** for this sub-area are divided in three main subgroups:

Safety in Urban Areas/ Road Transport Safety

a) 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

b) Development of a safe system strategy and a reduction number of accidents in urban areas,

c) 50% reduction in injuries and fatalities in road crashes with unprotected road users by 2030

d) Reduction of distraction of road users (drivers, riders, pedestrians,…) and of human errors with proper user information

e) Better prediction of road user behaviour, harmonisation of a prospective assessement and validation framework for road safety solutions (for regulatory and consumer asessmment)

f) Drastic reduction of road fatalities and crash injuries in low and medium income countries; safe design principles of the future road transport systems, better traffic flow in big cities, exchange of best practices and training

Waterborne Safety and Resilience

g) Prevent high consequence low frequency waterborne accidents including for example serious on-board fires.

h) Ensure healthy passenger shipping by preventing and mitigating the spread of contagious diseases and infections.

i) As the most frequent type of accident, prevent collisions, stranding and groundings at sea and inland.

Aviation Safety and Resilience

j) 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.

k) Saving lives following a crash (post-crash survivability).

l) Anticipate emergence of new threats that could generate potential accidents and incidents (short, medium, and long term).

m) Ensure safety through aviation transformation (from green/digital technologies uptake upto independent certification).

n) Maintain safety and resilience despite the scale, pace and diversity of new entrants.

For achieving these impacts, topics are considered addressing the following **issues**:

6.3.1. Safety in Urban Areas/ Road Transport Safety

1. Safe city streets; safety of unprotected road users in urban areas;

2. Safe human-technology interaction in the digital traffic system;

3. Safe inclusion of new means of transport into the traffic system (including safe transition to higher levels of automation);

4. Predictive safety assessement and validation framework (including new mobility patterns and societal changes and their link to road safety);

5. Care and rescue measures to minimize long-term effects (including emergency response);

6. Radical improvement of road safety in low and medium income countries (in particular in the Danube area, South East Europe, Africa).

6.3.2. *Waterborne Safety and Resilience*

7. Fire risk Causal Analysis, prevention and mitigation;

8. Infection Control on board large passenger ships - prevention, mitigation and management; Healthy ship design;

9. Navigational Accidents.

6.3.3. Aviation Safety and Resilience

10. Integrating Automation, Human Factors and external hazards;

11. Pre-normative research for fit for purpose regulations and social acceptance of level of risks. Safe & agile rulemaking and management systems incl. new aerial vehicles & players (e.g. drones, UAM, higher airspace operations, …);

12. Reducing the operational risk (including General Aviation and rotorcraft);

13. Improving post-accident survivability and prevention of safety related incidents in all phases of flight;

14. Safety data and Safety Intelligence;

15. Safe Design, Manufacturing and Certification.