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Study supporting the assessment of EU Missions and the review of mission areas

Mission areas review report

Independent Expert Report

Research and Innovation

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Study supporting the assessment of EU Missions and the review of mission areas

Mission areas review report

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2023 Directorate-General for Research and Innovation

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KEY DEFINITIONS, ACRONYMS AND GLOSSARY

Abbreviation/Acronym	Definition
CAP	Common Agriculture Policy
CCA	Climate Change Adaptation
CCS	Carbon capture and storage technologies
COP	United Nations Climate Change Conference
CO2	Carbon dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
C40	Global network of nearly 100 mayors of the world's leading cities
CWA	Clean Water Act
DG AGRI	Directorate-General for Agriculture and Rural Development
DG ENER	Directorate-General for Energy
DG ENV	Directorate-General for Environment
DG MARE	Directorate-General for Maritime Affairs and Fisheries
DG RTD	Directorate-General for Research and Innovation
DG SANTE	Directorate-General for Health and Food Safety
EAFRD	European Agricultural Fund for Rural Development
EPA	Environmental Protection Agency
EC	European Commission
EEA	European Environmental Agency

Abbreviation/Acronym	Definition
EHDS	European Health Data Space
EIB	European Investment Bank
EIT	European Institute of Technology
EMA	European Medicines Agency
EP	European Parliament
EPP	European People's Party Group
ESPAS	European Strategy and Policy Analysis System
EU	European Union
Eurostat	The statistical office of the European Union
FAO	Food and Agriculture Organisation
GHG	Greenhouse gases
ICT	Information and communication technologies
IEEP	Institute for European Environmental Policy
IPCC	Intergovernmental Panel on Climate Change
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
ITACC	Innovative Technology for Adaptation to Climate Change
JRC	Joint Research Centre
KIC	Knowledge and Innovation Community
KPI	Key performance indicator
LIFE	Financial instrument for the environment

Abbreviation/Acronym	Definition
MOIP	Mission-oriented innovation policies
MS	Member States
NCI	National Cancer Institute
NGO	Non-governmental organisation
NWQMS	National Water Quality Management Strategy
NCD	Noncommunicable diseases
OECD	Organisation for Economic Development Cooperation
R&D	Research and development
R&I	Research and innovation
SRIP	Science, research and innovation performance
SOC	Soil organic carbon sequestration
SIP	Strategic Innovation Promotion Program
SDGs	Sustainable Development Goals
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
USPTO	United States Patents Office
WHO	World Health Organisation

ABSTRACT

This study reviews the current and future policy relevance of the five mission areas by assessing the research and innovation (R&I), economic, social and environmental trends influencing each area. The 'societal relevance' of each of the five mission areas is not contested as they all address complex challenges facing the EU that require action on the part of governments, businesses, education and research institutions and civil society. The mission areas are, to a greater or less extent, interlinked and the review underlines the systemic nature of the challenges and the need for concerted action to optimise synergies in implementing missions. The need for sustained R&I investment is evident for all five areas with differences in the extent to which weight is given to more 'research' (new discoveries) to more 'innovation' (implementation of existing or novel solutions). The scope of each area is sufficiently broad to stand the test of time to the 2030 horizon addressed by each respective mission. The review proposes three recommendations for the way in which mission areas should be defined and selected and their continuing relevance monitored.

RESUME

Cette étude examine la pertinence politique actuelle et future des cinq domaines de mission en évaluant les tendances en matière de recherche et d'innovation (R&I), d'économie, de société et environnementales qui influencent chaque domaine. La pertinence sociétale de chacun des cinq domaines de mission n'est pas contestée, car ils abordent tous des défis complexes auxquels l'UE est confrontée et qui nécessitent une action de la part des gouvernements, des entreprises, des établissements d'enseignement et de recherche et de la société civile. Les domaines de mission sont, dans une plus ou moins large mesure, liés entre eux et l'analyse souligne la nature systémique des défis et la nécessité d'une action concertée pour optimiser les synergies dans la mise en œuvre des missions. La nécessité d'un investissement soutenu dans la R&I est évidente pour les cinq domaines, avec des différences dans la mesure où l'on accorde plus d'importance à la recherche (nouvelles découvertes) qu'à l'innovation (mise en œuvre de solutions existantes ou nouvelles). Le champ d'application de chaque domaine est suffisamment large pour résister à l'épreuve du temps jusqu'à l'horizon 2030 visé par chaque mission respective. L'étude propose trois recommandations sur la manière de définir et de sélectionner les domaines de mission de surveiller leur pertinence continue au fil du temps.

EXECUTIVE SUMMARY

This study reviews the current and future policy relevance of the five mission areas by assessing the research and innovation (R&I), economic, social and environmental trends influencing each area. The five mission areas, approved by the European Council and European Parliament in the 2021 Horizon Europe Regulation, are: adaptation to climate change, including societal transformation; cancer; healthy oceans, seas, coastal and inland waters; climate-neutral and smart cities; soil health and food. The review is based on data and information collected through a literature review and desk research as well the consultation of targeted stakeholders and resources available to the study team.

MISSION AREA: ADAPTATION TO CLIMATE CHANGE, INCLUDING SOCIETAL TRANSFORMATION.

The mission area is anchored in a set of overarching EU policies and commitments responding to anthropogenic induced climate change. The mission area is fit for purpose and likely to stand the test of time due to its broad and flexible coverage of key community systems and enabling conditions for resilience. Climate change adaptation (CCA) is a relatively newer subject than climate change mitigation. The mission area is timely as it helps place adaptation at the top of (notably, local and regional) policy agendas. The trend in climate-related economic losses is worsening, while the commitment to climate actions by local authorities is growing. This reinforces the relevance of the mission without a need for a re-definition of the mission area.

R&I is required to produce new evidence tailored to the needs of regional and local actors as a basis for more effective CCA policies including addressing knowledge gaps that can pave the way for more systemic adaptation. Equally important is improved knowledge on the costs and benefits from investing in CCA measures. Moreover, no standardised approach to measuring climate resilience has emerged. Finally, inputs from social and political sciences on effective and inclusive governance models for adaptation are required to open room for wider participation of citizens. Such R&I efforts require a transdisciplinary approach.

Compared to international comparators (Japan and Iceland), the CCA scope has a similarly broad coverage of key systems, however economic sectors are focused on more explicitly as is the incorporation of businesses as a target group. Enhanced synergies between mitigation and adaptation are an explicit orientation in the Icelandic plan, a feature that is more implicit in the both the EU's mission and mission area. Exploiting synergies between adaptation and mitigation efforts may help to achieve climate resilience more effectively.

MISSION AREA: CANCER

Cancer is the second leading cause of death in Europe and a growing challenge. While there is a slight reduction in mortality due to screening campaigns and improved diagnostics and treatment, the number of diagnosed cases will increase by 25% by 2035 if no action is taken. R&I plays a fundamental role in addressing challenges along the whole cancer control pathway, from prevention to end-of-life care or survivorship, and for improving cancer outcomes. Europe is a global leader in cancer discovery science but more effort to investigate certain types of cancer is required. Many types of cancer can be prevented, yet cancer prevention research is not sufficiently funded. Moreover, the ability to convert research discoveries into therapeutic innovations is hindered by regulatory and implementation constraints, and scale-up challenges. There is a need for more interdisciplinarity and for a greater emphasis on demographic (e.g. the impact of an ageing population), geographical

and social dimensions (e.g. non communicable diseases such as obesity which are a major cause of cancer) of cancer and on access to prevention and care.

The mission area should cover the entire cancer care pathway, which implies a mission area scope much wider than medical R&D. Patient education, communication and trust in health systems continue to represent major barriers to cancer screening and to controlling the disease and data collection. Hence, prevention, treatment and care require well-functioning and resilient health care systems in all EU countries and regions. This finding is in line with international comparators, such as the US Cancer Moonshot 2.0, which have moved away from a technoscientific to a socio-cultural approach involving citizens and patients.

The mission area's definition is focused (i.e. targeting cancer is concrete and targeted) but still wide enough (i.e. cancer is not one disease but a disease with multiple forms and types). Pressures to deal with cancer are not going away and, in the short to medium term, it is unlikely that scientific breakthroughs will make the mission area less relevant.

MISSION AREA: HEALTHY OCEANS, SEAS, COASTAL AND INLAND WATERS.

Oceans, seas, coastal and inland waters form the water-cycle continuum, on which all planetary forms of life depend upon. The hydrosphere is a climate regulator, dominating the planetary carbon, water and heat budgets: oceans and waters influence climate and weather patterns, provide us with drinking water and protein food. In addition, the planetary waters are also a place of recreation, trade and connectivity for humans. The hydrosphere is, however, seriously endangered. As a result of unsustainable greenhouse gas emissions (GHGs), emission of land and water based pollutants, and of the overexploitation of biological resources and natural ecosystems, the hydrosphere has warmed, become more acidic, less oxygenated, poorer in biological resources and less able to provide services to the human population, in terms of food availability, of drinking-water resources, of resilience to extreme weather conditions and even of tourism, ultimately affecting human well-being.

The mission area is a multidimensional space influenced by varied external factors, such as environmental conditions, ecological stressors, societal approaches, political governance, and management. A series of studies have demonstrated the state of degradation of the water continuum, and provided evidence to define the ocean, seas, and coastal and inland waters as an area for urgent and unabated policy attention and for R&I actions. Understanding the complexity of the interconnections between the water system's health, the climate, biodiversity and food provision, is fundamental to developing the required flexible capacity to manage challenges simultaneously, in a systemic perspective. R&I on the interdependencies between the elements of the water-climate nexus, and how this impacts life on Earth is at the core of a fuller understanding of the dynamics in this mission area. The novel dimension of ocean ethics should be better highlighted to produce a cultural shift and behavioural change at the individual level, regarding the impact of human activity on the hydrosphere. The use of digital technologies for representing and managing the water continuum are also a rather novel element for R&I action, which would support a modern ocean governance and management system.

The review of approaches to addressing ocean and waters challenges in other countries suggests a more targeted approach to improve water management practices, reduce pollutants (e.g. plastics) or protect marine environments. A fully-fledged mission-oriented innovation policy does not appear to have been adopted, even if there is a shift towards such an approach. The pioneering nature of the mission in this area is evident.

MISSION AREA: CLIMATE-NEUTRAL AND SMART CITIES.

The mission area climate-neutral and smart cities is tightly linked to the aim of achieving a climate-neutral economy in Europe by 2050 and the green and digital 'twin transition'. The mission area is builds on previous cross-national city initiatives for climate action. Cities can only achieve net-zero greenhouse gas emissions (GHG) through deep decarbonisation and systemic transformation. The mission area scope addresses sustainable development goals (SDGs) 11 (sustainable cities and communities) and 13 (climate action) and significant societal challenges in domains such as mobility and transport, urban greening, energy provisioning, and buildings. Tackling GHG emissions of cities has a high potential to deliver rapid and large-scale contributions to decarbonisation while creating co-benefits with respect to air quality, heat stress, as well as mental and physical health. However, the mission area conveys a rather technocratic, 'smart' vision, which may weaken efforts towards citizen engagement and stakeholders, when communicating emphasise instead the mission's contribution to 'green' and 'healthy' cities.

There are a substantial R&I needs for climate-neutral cities. However, R&I alone is insufficient and the main challenge for cities in transitioning to climate neutrality is in implementation. While R&I on digital technological and systems are important, the urban transition to climate neutrality requires innovations in social, creative, organisational, and financial dimensions. This highlights the need to consider non-technological innovations and the important role of citizen science and participatory R&I, before and *during* implementation. A series of key trends affecting pathways to climate-neutral and smart cities, such as urbanisation, an ageing population, digitalisation, climate change, and migration inflows have intensified. Europe has moved even away from the trajectories needed to comply with its climate targets in critical domains linked to urban development. In short, European cities which have become more vulnerable to transnational and global trends, while increasingly lacking the financial capacities to push forward a climate neutral transformation process.

Most mission-oriented innovation policies in other countries target industries rather than cities, adopting a sectoral approach rather than a holistic, placed-based innovation focus. Moreover, other missions place greater emphasis on the development of new technologies and demonstration of tangible, industrially scalable outcomes. The mission area requires a demanding mission-oriented innovation policy of a transformative type, implying major changes in everyday life, governance, and business practices.

MISSION AREA: SOIL HEALTH AND FOOD.

The environmental and societal consequences of deteriorating soil health conditions put at risk the continued capacity of soils to support ecosystem services such as nutritious and safe food, storing and purifying water, capturing carbon from the atmosphere, nutrient cycling supporting crop productivity, preserving and protecting biodiversity by preserving habitats both above and within the soil and supporting the quality of landscapes and greening of towns and cities. The choice of soil health and food fits the imperatives of mission-oriented innovation policy to tackle societal challenges, contributing notably to SDG 2 (zero hunger), SDG 6 (clean water and sanitation), SDG 13 (climate action) and SDG 15 (life on land). A second rationale is the natural capital dimension for which there has been relatively little policy progress in the EU. Current soil management practices mean that 60-70% of EU soils are unhealthy, with a further percentage of unhealthy soils due to poorly quantified pollution issues. A healthy soil goal through a radical change in current land management practices is both feasible and necessary. Soils will also benefit from improvement to indirect drivers of change such as reductions in air pollution and carbon emissions.

R&I is a core mechanism to mitigate soil pollution and promote soil conservation measures is essential to support CCA. R&I activity in agriculture and food is significant, with trends such as precision agriculture and the implementation of digital technologies in farming. However, R&I in agriculture, urban soils and forestry should take account of the practices supporting the adoption of new technologies and practices. Research on the factors influencing the adoption of innovations such as climate-smart agriculture practices is required.

Missions in non-EU countries address either food related topics or environmental sustainability with the combination of issues rare. A common approach of agriculture and soil related missions in Australia and New Zealand is an emphasis on more stakeholder engagement and dialogue during both the scoping of mission areas as well when implementing the corresponding mission.

OVERALL CONCLUSIONS

Five overall conclusions are developed based on the review of the five mission areas:

- The 'societal relevance' of the five mission areas is not contested as they address complex challenges facing the EU that require action on the part of governments, businesses, education and research institutions and civil society.

- The mission areas are, to a greater or less extent, interlinked and the review underlines the systemic nature of the challenges they address and the need for concerted action to optimise synergies in implementing missions.

- The need for sustained R&I investment is evident for all five areas with differences in the extent to which weight is given to more 'research' (new discoveries) to more 'innovation' (implementation of existing or novel solutions).

- There is a need in all the mission areas for an increased focus on interdisciplinary R&I including a greater integration of social science and humanities. This includes R&I on inclusive governance and encouraging adoption of solutions by specific user groups.

- The scope of each area is sufficiently broad to stand the test of time to the 2030 horizon addressed by each respective mission.

RECOMMENDATIONS

Three recommendations are made:

- Define mission areas based on an objective evidence-base (including assessment of mega trends, foresight, etc.) and agree on criteria and the procedure for ranking alternative mission areas, giving sufficient time and means for citizens to propose ideas that feed into a high-level policy debate and final decision.

- The definition and selection of mission areas requires a deeper understanding of the social factors driving or hindering change and the social innovations required.

- There should be a structured and on-going process of updating and anticipating the key trends and factors influencing the five mission areas (and pre-identification of future mission areas), for instance by making use of R&I foresight, citizen engagement, etc.

1. Introduction

1.1. Scope and aim of the report.

In November 2022, the Directorate-General for Research and Innovation (DG RTD) commissioned a study supporting an assessment of the EU Missions, the review of mission areas and the analysis of the missions' portfolio of instruments and actions. The five mission areas, approved by the European Council and European Parliament by the adoption of the Horizon Europe Regulation[1], are:

1. Adaptation to Climate Change, including Societal Transformation.
2. Cancer.
3. Healthy Oceans, Seas, Coastal and Inland Waters.
4. Climate-Neutral and Smart Cities.
5. Soil Health and Food.

Based on these areas, five EU missions have been designed and launched, namely:

- Adaptation to Climate Change: Support at least 150 European regions and communities to become climate resilient by 2030
- Cancer: Improving the lives of more than 3 million people by 2030 through prevention, cure and for those affected by cancer including their families, to live longer and better
- Restore our Ocean and Waters by 2030
- 100 Climate-Neutral and Smart Cities by 2030
- A Soil Deal for Europe: 100 living labs and lighthouses to lead the transition towards healthy soils by 2030.

This report **compiles the findings of the review of the five mission areas.** Following this introductory section, which provides a short summary of the methodology used, the report is structured in five main sections, one for each of the mission areas followed by a final section setting out the cross-cutting conclusions.

1.2. Summary of the methodology for the mission area review

The mission areas were analysed taking account the current and future broad research and innovation (R&I), economic, social and environmental trends and factors. Five main research questions are addressed:

[1] Regulation (EU) 2021/695 of the European Parliament and of the Council of 28 April 2021. Establishing Horizon Europe – the framework programme for research and innovation, laying down its rules for participation and dissemination, and repealing regulations (EU) No 1290/2013 and (EU) No 1291/2013

- How well does the definition of the five mission areas address the major challenges the EU faces?
- Is the key role of R&I in addressing the mission area challenges adequately explained?
- Has the relevance of the mission areas, as initially defined, changed over time given developments in the R&I, environmental, economic and social landscapes?
- Is there enough flexibility built into the mission area definition to adapt to such changes?
- To what extent does the definition of the mission areas align with or differ from those of mission-oriented innovation policies (MOIP) in countries beyond the EU (e.g. Japan, the USA, etc.)? What insights does this provide for the missions?

The review process, as illustrated in Figure 1, was structured around a set of analytical methods.

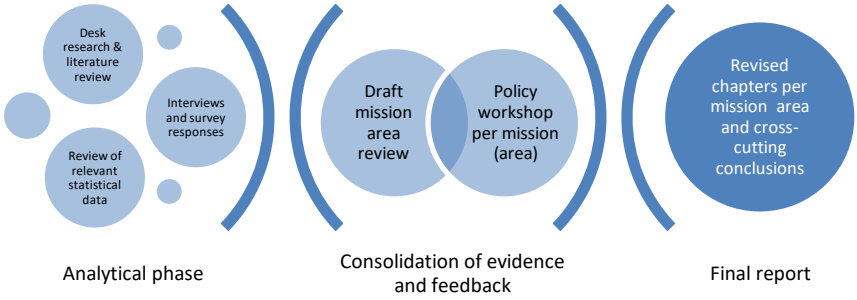

Figure 1. Simplified methodological process for the mission areas review.

Source: own elaboration

The research questions have been firstly informed by secondary research:

- Insights derived from a literature review of academic journal articles which was carried out across the five mission areas. The full literature review is available as an annex to the final report.
- Evidence from desk research covering technical (e.g. foresight, R&I analysis) studies, policy reports and grey literature.
- Review of relevant data on recent trends in socio-economic, environmental, health, etc. statistics.

In addition, the views and opinions on the continuing relevance of and trends impacting the mission areas have been gathered from a broad range of stakeholders through:

- 63 interviews, including those carried out with selected experts with in-depth knowledge of specific topics or trends of the mission area (such as senior researchers from academic or research and technology organisations, experts from think tanks and specialist NGOs);

- 342 responses to the survey that included questions addressing the relevance and scope and opportunities for respondents to provide written comments;

- 132 participants to five online policy workshops held during the week of 11 April 2023.

The quantitative and qualitative data and evidence collected has been triangulated[2] (for instance opinions of interviewees, survey participants replies to open questions, or workshop participants are linked, wherever possible, to the studied academic literature, grey literature and/or relevant statistical data or other quantitative evidence) to provide as strong and robust an evidence base as possible for the review. A fuller explanation of the methodology for the entire study and relevant annexes (such as the literature review, survey results, etc.) is available in the overall final study report.

The chapters of the report have been produced, under the guidance of Alasdair Reid, by:

- Claire Nauwelaers and Céline Phillips - Adaptation to Climate Change, including Societal Transformation.

- Jelena Angelis & Ebba Hallersjö - Cancer.

- Ilaria Nardello & Elina Griniece - Healthy Oceans, Seas, Coastal and Inland Waters.

- Harald Wieser & Peter Kaufmann - Climate-Neutral and Smart Cities.

- Matthijs Janssen - Soil Health and Food.

[2] Methodological triangulation involves using more than one kind of method to study a research question or hypothesis. It has been found to be beneficial in providing confirmation of qualitative and quantitative findings, increased validity and enhanced understanding of studied questions.

2. Mission area: adaptation to climate change, including societal transformation.

2.1. The scope and definition of the mission area

Initially, the European Council selected two topics, climate change adaptation (CCA) and societal transformation that were merged into a single topic on which the mission board worked. In the 2020 mission board proposal, 'societal transformation' was dropped and when the mission was launched in 2021 'Adaptation to Climate Change' was retained as a title fit for communication purposes ('societal transformation' being judged as too vague).

The **mission area is anchored in a set of EU policies**. Firstly, adaptation is enshrined in the Paris Agreement[3] to which the EU is committed (UNFCCC, 2015). Secondly, the mission area is in line with the second EU Adaptation Strategy (EC, 2021c)[4] with the European Green Deal as an overarching strategic umbrella (EC, 2019). Thirdly, Article 5 of the 2021 European Climate Law[5] foresees that "the relevant Union institutions and the Member States shall ensure continuous progress in enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change in accordance with Article 7 of the Paris Agreement" and "Member States shall adopt and implement national adaptation strategies and plans, taking into consideration the Union strategy on adaptation to climate change and based on robust climate change and vulnerability analyses, progress assessments and indicators, and guided by the best available and most recent scientific evidence."

Most recently, the 2022 IPCC report, prepared by 700 scientists from 91 countries underlines the **relevance and urgency of a mission area devoted to climate change adaptation** (CCA): *"Despite progress, adaptation gaps exist between current levels of adaptation and levels needed to respond to impacts and reduce climate risks (high confidence). Most observed adaptation is fragmented, small in scale, incremental, sector-specific, designed to respond to current impacts or near-term risks, and focused more on planning rather than implementation (high confidence)"* (IPCC, 2022).

By focusing on a challenge that is highly timely and urgent, the mission area fits with the overall expectations set for the mission to "*support Europe's transformation into a greener, healthier, more inclusive and resilient continent*" by providing "*a new way to bring concrete solutions to some of our greatest challenges*" and "*bring tangible benefits to people in Europe and engage Europeans in their design, implementation and monitoring*" (EC, 2021c).

Adaptation means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause or taking advantage of opportunities that may arise. Examples of adaptation measures include nature-based solutions to protect flooding, large-scale changes, such as making critical infrastructure climate resilient against sea-level rise, as well behavioural shifts, such as individuals reducing their water

[3] Article 2.1 sets the goal of increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and article 7 sets a goal of enhancing adaptive capacity, strengthening resilience and reducing vulnerabilities to climate change.

[4] Except for its component of international action.

[5] REGULATION (EU) 2021/1119 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999.

consumption. In essence, adaptation can be understood as the process of adjusting to the current and future effects of climate change.

Mitigation means making the impacts of climate change less severe by preventing or reducing the emission of greenhouse gases (GHG) into the atmosphere. Mitigation is achieved either by reducing the sources of these gases — e.g. by increasing the share of renewable energies or establishing a cleaner mobility system — or by enhancing the storage of these gases — e.g. by increasing the size of forests. In short, mitigation is a human intervention that reduces the sources of GHG emissions and/or enhances the sinks.

Maladaptation means actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas (GHG) emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence.

Figure 2 Climate change adaptation, maladaptation and mitigation definitions

Sources: adaptation and mitigation: European Environmental Agency[6]; maladaptation: (IPCC, 2022)

Adapting to the unavoidable impacts of climate change adaptation is needed at the same time as mitigating climate change. Both efforts are complementary and mutually reinforcing, as stated by all interviewees without exception, and also clearly acknowledged by the IPCC (2022) and the above-mentioned EU strategies. **Adaptation and mitigation both contribute to addressing climate change challenges**, and even more so when synergies are built between the two, avoiding maladaptation – see figure below (OECD, 2021a).

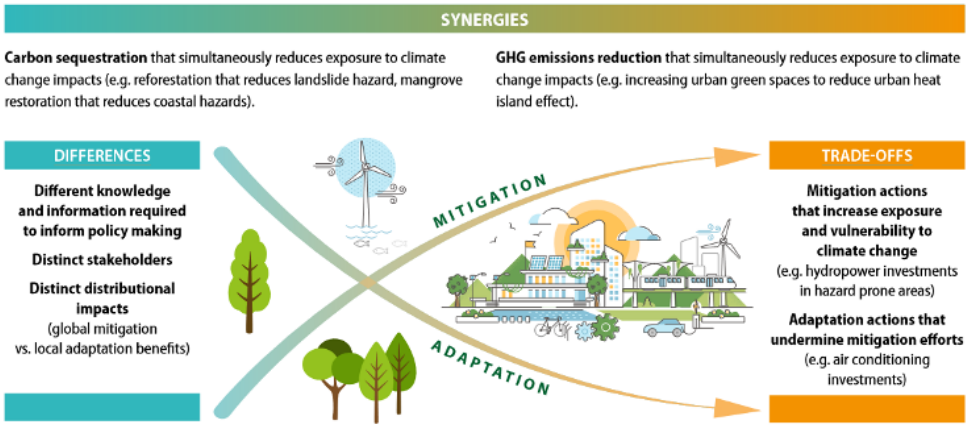

Figure 3. Synergies between mitigation and adaptation to climate change

Source: (OECD, 2021a)

The CCA topic is a very relevant one for a mission: the urgency to be prepared for climate change is there, the IPCC is certain, and some projections are apocalyptic! Awareness is growing but it is not sufficient. The need to act and look 'beyond averages' must be forcefully pushed. Hence the choice of this topic for the mission is absolutely timely and relevant.

[6] https://www.eea.europa.eu/help/faq/what-is-the-difference-between

Mitigation and adaptation go hand in hand: hence there is the crucial need for heavily supporting efforts to CCA" (an interviewee).

Climate change adaptation and mitigation policies have been to a large extent separately addressed in the past, and there are good reasons for distinct policies: mitigation is chiefly about developing solutions to decarbonise all our activities, from transport to energy, while adaptation aims at finding solutions to maintain essential services and activities despite severe impacts of climate change on ecosystems, infrastructure and people. The type of R&I needs also differ. Under mitigation, the target is the development of technologies or new organisational models for the circular economy, the production of energy from green sources, etc. In contrast, under adaptation research efforts target e.g. the development of nature-based solutions to address coastal erosion or the development of new financial models for adaptation finance. Limiting climate change through mitigation action has global public good benefits with overall reductions of GHG at planetary level translating into a stabilising climate, while benefits from adaptation actions are mostly accrued locally, reducing loss and damages from floods or wildfires (Swart and Raes, 2007). This creates different needs and levels of coordinating action. The type of knowledge needed to inform adaptation and mitigation policies is different. While mitigation policy is grounded in information on the source, type and amount of GHG generated by different economic activities, adaptation measures are determined by the estimated scale of local climate change impacts.

As a result, distinct stakeholders have been involved in the implementation of adaptation and mitigation policies (Denton et al., 2014) (UNFCCC, 2020). Yet, **there are synergies between adaptation and mitigation efforts that can help to achieve climate resilience more effectively**. Forest or mangrove restorations, for example, create an opportunity to increase carbon storage capacity, while also contributing to reduce weather-related risks, such as landslides or coastal storm surges. Identifying these opportunities can lead to better understanding and avoiding trade-offs and to developing policy measures that are mutually reinforcing (OECD, 2021a).

Analysis of United States Patents Office (USPTO) patents shows that, "*from a technological perspective, climate change mitigation and adaptation are complements: on average, 26% of adaptation technologies also help in mitigation. […] Well-designed policy may exploit and strengthen these complementarities to ensure that climate change technologies serve the twin goals of adaptation and mitigation*" (Hötte and Jee, 2022). However, the patenting of technologies supporting adaptation did not grow much over the past decades and their development rate has started picking up only very recently. **Public support might be vital in further promoting this trend especially for science-intensive technologies**, as private sector incentives to engage in basic research are currently low, especially in contexts characterised by high levels of uncertainty in policy approach (Kyaw, 2022) and despite their pivotal role in producing eco-innovations (Fagerberg, 2018; Popp, 2017). However, even public agents such as universities deserve attention in light of the current reframing of innovation policy agendas addressing complex challenges such as adaptation to climate change (Ghosh *et al*., 2022; Parker and Lundgren, 2022; Fagerberg, 2018). Building closer linkages between mitigation and adaptation efforts is advocated both by IPCC and OECD:

- "Strengthening linkages between climate change adaptation and mitigation policies can improve the efficiency and effectiveness of actions in support of a low-carbon, climate-resilient economic development." (OECD, 2021a).

- "Pathways for advancing climate resilient development are development trajectories that successfully integrate mitigation and adaptation actions to advance sustainable development" (IPCC, 2022).

DEFINING THE MISSION SCOPE

Working on the mandate given by EU authorities, the mission board proposed a mission with the following title: “a Climate Resilient Europe: Prepare Europe for climate disruptions and accelerate the transformation to a climate resilient and just Europe by 2030” (EC, 2020). The mission board based its work on a multiplicity of sources of evidence, notably from IPCC and EEA. A foresight report was prepared for this mission area and involved interactions with the mission board and other experts, scenario building exercises and an analysis of CCA-relevant projects (EC, 2021b). The foresight exercise was meant to complement the mission boards’ deep and wide-ranging expertise by exploring longer-term time horizons, up to and beyond the year 2050. Building on existing future-oriented work, the project employed dedicated foresight methods, in particular workshops and a Delphi survey, to explore this time horizon in a systematic manner, and involving experts and stakeholders. The foresight exercise addressed the areas of risk management, financial risk protection, social infrastructure, health, water, food/agriculture, and ecosystems. In addition, the mission board members met with a variety of stakeholders in 2019 and 2020, which nurtured the mission board proposal. **Three key orientations**, in line recent research findings, were considered in the proposal of the mission board:

1. Adapting to climate change is a complex and pervasive challenge requiring a systemic approach;

2. A territorial cohesion dimension needs to be at the forefront of adapting to climate change;

3. Attention and efforts towards climate change adaptation need to be stepped up drastically emphasising the costs of non-action.

Adapting to climate change is a complex and pervasive challenge requiring a systemic approach

The mission board proposal proposed that the “mission employs an **integrated and systemic approach to risk management and resilience building**, moving away from piecemeal sectorial and linear cause-effect-solution focus” (EC, 2020). The scientific community agrees that the process of mitigation and adaptation will not succeed or will be hampered if policy responses are not mainstreamed across policy areas such as critical infrastructures or ocean resources management. For example, adapting to climate change requires massive societal transformations that cannot happen without an integrated intervention in infrastructures. Despite the tendency to consider one infrastructure at a time and intervene on it in isolation from others, practices and social arrangements depend on constellations of intersecting infrastructures (Cass et al., 2018), which need to be rethought at the system level in order to support change. Actions that are taken in one sector or intervention area without taking into consideration indirect impacts on other areas can lead to maladaptation: “maladaptation can be avoided by flexible, multi-sectoral, inclusive and long-term planning and implementation of adaptation actions with benefits to many sectors and systems (high confidence)” (IPCC, 2022).

“Transformative adaptation is going to come to the fore in the future: small measures work in the short term but they are insufficient in the long term. More fundamental changes are needed, structural changes and shifts affecting citizens’ life. What is needed is to prepare for changes, not reacting ex post. Attention to transformational adaptation is nascent: this is where the mission can help.” (an interviewee)

The mission's board scope definition rightly emphasises the interlinkages between five interdependent key community systems for which 'transformative pathways' are needed:

- regenerating community and social infrastructure;
- protecting human health and wellbeing;
- restoring nature, biodiversity and ecosystems services;
- rethinking water management;
- reviving landscapes and sustainable food systems,

and four 'enabling conditions'

- facilitating inclusive and deliberative governance processes for just transitions;
- providing access to data, knowledge, and digital services;
- strengthening education, communication and a better understanding of behavioural change;
- strengthening sustainable and circular local economies; mobilising funds and resources.

Figure 4 indicates that the mission's community systems approach matches closely those identified by other initiatives, namely: the Regions Adapt initiative[7] (launched in 2002), the IPCC's scientific communities (2022), the Global Commission on Adaptation (2019) and the OECD (2021). The experts interviewed agreed that **the scope of the mission is well suited to address the challenges of climate change adaptation**.

EU Mission Board	Regions Adapt initiative	IPCC	Global Commission on Adaptation	OECD
Regenerating community and social infrastructure	Infrastructure (including transport and energy) and territorial planning; economic impacts and opportunities; social adaptation and impacts	Cities, settlements and key infrastructure	Cities and urban areas; infrastructure; finance	Infrastructure
Protecting human health and wellbeing	Resilience and disaster risk reduction	Health, wellbeing and the changing structure of communities; poverty, livelihoods and	disaster risk management	Development co-operation; losses and damages from climate change

[7] https://regions4.org

EU Mission Board	Regions Adapt initiative	IPCC	Global Commission on Adaptation	OECD
		sustainable development		
Restoring nature, biodiversity and ecosystems services	Forestry, protected areas and biodiversity	Terrestrial and freshwater ecosystems and their services; oceans and coastal ecosystems and their services	Natural environment	Biodiversity; nature-based solutions for climate resilience
Rethinking water management	Water resources and management	Water	Water	Water - sea level rise and coastal climate risks
Reviving landscapes and sustainable food systems	Agriculture and zootechnics	Food, fibre and other ecosystem products	Food security	Agriculture

Figure 4. Comparison of the systems identified by the EU mission board (2020) and other international frameworks

Source: author based on cited references on top of the columns

The mission board placed an emphasis on the same enabling conditions as the IPCC (2022), but also identified the need to: strengthen education, communication and have a better understanding of behavioural change; strengthen sustainable and circular local economies.

"The mission scope definition is fine, it is broad: you can't go wrong with this definition."

"The scope of the mission is wide enough to encompass the various types of climate risks; the definition of intervention areas and enabling factors is also wide enough and flexible to accommodate needs for various types of territories."

"The definition and scope of CCA adopted by the mission is good. There are 100 ways to elaborate on the scope, which differ only slightly from each other: the one of the mission is as good as many others. It is understandable and carries a time perspective. It is also sufficiently broad to accommodate for upcoming possible changes in CCA challenges." (quotes from interviewees)

Territorial cohesion should be at the forefront of adapting to climate change

The mission board's proposal placed an emphasis on the diversity in vulnerability, climate risks, response capacity and level of preparedness across EU territories. As Feyen et al. (2020) note "the burden of climate change shows a clear north-south divide, with southern regions in Europe much more impacted, through the effects of extreme heat, water scarcity, drought, forest fires and agriculture losses". The mission board advocated a balanced

improvement in resilience 'leaving no territory behind', thus incorporating the 'just' dimension in the overall mission vision. The board proposed "a twinning mechanism bringing together innovation leaders and more modest performers" (EC, 2020). The understanding that climate change impacts cross borders also justifies an inclusive approach, i.e. one that is not limited to the creation of a few 'islands of excellence on adaptation' in Europe.

"There is a solidarity dimension in CCA: territories are not competing against each other (in contrast with mitigation for which there are important markets and competing players); to the contrary everybody is in the same CCA boat and if some territories are not adapting, it creates problems for the others, e.g. in terms of trade disruption." (interviewee)

"The state of preparation with respect to CCA differs a lot across EU regions/localities. This is well taken into account in a mission goal definition that is expressed in relative terms, i.e. being better prepared than it would have been the case without the mission." (interviewee)

In addition, social justice is also included in the mission's scope. This is consistent with findings about the state-of-the-art in adaptation policies in Europe: "*the social justice aspects of adaptation are not yet integrated in the reporting of all countries. However, these increasingly important aspects aim to address the uneven distribution of climate risks, which affect vulnerable groups the most. More positively vulnerable groups have a role in developing national and regional adaptation policies in several countries and are involved in the prioritising of adaptation measures*" (EEA, 2022).

> In a world of increasing and mutually reinforcing climate disruptions and socio-economic and environmental challenges, the vision of this mission is to turn the urgent challenge of adapting to climate change into an opportunity to make Europe resilient, climate-prepared and *just*.

Figure 5. Proposed vision by the mission board

Source: (EC, 2020), emphasis added

CCA efforts need to be stepped up by drastically emphasising the costs of non-action

The mission proposal starts from the premise that **long-term benefits will outweigh the immediate costs of investments in climate change adaptation**, and that adaptation strategies and solutions have not received the attention they deserve until recently. Although the demonstration of cost-benefits ratio and the costs of non-action is far from easy to articulate, such a point of departure concurs with recent EIB statements: "adaptation investment needs in the EU are estimated to range between EUR 35 billion and 500 billion annually, the large variation reflecting different underlying assumptions and methodological approaches. On the other hand, it is estimated that exposing the EU economy to global warming of 3°C above pre-industrial levels could result in an annual loss of at least EUR 170 billion (1.36% of EU GDP). Losses are distributed unevenly, raising particular concerns on vulnerable groups, coastal areas and regions that may already face challenges due to unemployment and low economic growth" (EIB, 2021).

2.2. Review of the mission area

2.2.1. The role of R&I in addressing the challenges faced by regions and local communities

Regions and local communities face multiple challenges to address CCA: understanding the current status and projections of the impacts of climate change for their territories; quantifying what is required to be resilient at a given moment in time; identifying transformative solutions; overcoming the barriers to political engagement for long-term adaptation pathways and assessing achievements. R&I can contribute to address all these challenges.

Scientific and research efforts are needed to produce new robust evidence tailored to the needs of regional and local authorities as a basis for more effective CCA policies in the form of: "data that are specific to local context, scenario modelling, decision making tools (for instance evaluating which option is the best approach) and robust datasets spanning longer time periods. The importance of local data for local authorities is a key theme with many noting that data is often not specific to the region and downscaling national data is not easy or even possible" (gancheva et al., 2020).

Scientific research efforts have mainly adopted sector-specific or region-specific approaches. The literature emphasises the adoption of a technology-based approach not just to addressing climate change mitigation but also to help communities in adapting to climate change and adjust to rapidly changing climatic conditions (IPCC, 2022). According to Hötte and Jee (2022), examples of this can be found in climate-smart agriculture, which could help communities in adapting to environmental threats, or new drugs and vaccines to protect citizens against new viruses or diseases brought by fast changing climate conditions. However, the limit of existing studies on adaptation to climate change is that they predominantly focus on specific regions or sectors or climate risks (e.g. droughts) (Ferreira et al., 2020), paying insufficient attention to heterogeneity across Europe. There is insufficient understanding of the indirect and spill-over effects of climate change across different sectors (Gancheva et al., 2020). **Hence new research is needed to fuel the mission with more elaborated evidence related to knowledge gaps on complex issues:** *"Knowledge gaps related to non-climatic factors, cross-border and international climate risks, cross-sectoral interactions and complex, compound and cascading risks tend to persist. Addressing these knowledge gaps is needed to pave the way for more systemic adaptation"* (EEA, 2022).

Equally important as new knowledge on current and future climate change, risks and impacts, is improved **knowledge on costs and benefits from investing in climate adaptation measures.** On both fronts, measuring costs and measuring benefits, a lot of methodological issues remain unsolved, e.g. the identification of 'adaptation-relevant' investments and the distinction between nature- and man-driven climate hazards. These are compounded by the high level of uncertainty on evolutions in climate change and intensity and effectiveness of mitigation efforts.

Current methods for monitoring and evaluating climate change adaptation use a variety of indicators ranging from climate parameters, the impacts of climate change, vulnerability to climate change, progress made in implementing actions and, more rarely, estimations of the capacity to respond to a given impact. To date, **no standardised approach to describe climate resilience** has emerged. This leads to difficulties in communicating simply about the impact of climate change adaptation policies and the progress they have been able to bring.

The mission, with an important role given to R&I, is timely and responds to a gap in knowledge necessary to respond to the societal challenge it addresses at regional and local levels.

Specific Challenge	Expected contribution of R&I
Limited awareness and low sense of urgency of the need to adapt to the impacts of climate change in addition to mitigation	Developing new knowledge to understand and measure socio-economic and environmental impacts of adaptation (territorial resilience) and relate them with costs in investing in adaptation to demonstrate the cost of non-action.
Insufficient political commitment towards CCA	Developing action research to identify barriers and solutions for political engagement in adaptation strategies and action
Underdeveloped evidence in the form of space-based information on current and future climate-related hazards, vulnerabilities and risks	Developing "more and better data and statistics that are timely, accurate, disaggregated, people-centred, accessible and user-friendly also for audiences with limited technical capacities" (EC, 2020).
Weak capacity of local and regional authorities to access and use policy-relevant evidence Need for adequate governance to develop visions and transformative pathways to resilience	Developing action research to identify barriers and solutions for regional and local authorities to design and implement effective and prospective CCA strategies.
Fragmentation and unnecessary duplication of adaptation solutions Lack of systemic and transformative adaptation solutions crossing sectors and adopting longer time perspective	R&I activities on new adaptation solutions and models[8]. New technologies and societal innovations for regional and local uptake and deployment of effective early warning and monitoring systems.
Climate adaptation gap: weak incorporation of climate-induced risks in investment and insurance products	Development of suitable models and mechanisms for adaptation finance and risk-transfer mechanisms.

Figure 6. Examples of expected contributions of R&I to addressing the mission area

Source: author based on mission board report (EC, 2020), foresight report for the mission board (EC, 2021b) and studies by EEA and IPCC

[8] Such as: nature-based solutions for adaptation and restoration of ecosystems towards resilience; solutions addressing vulnerabilities and risks in coastal areas; new models of resilient agricultural systems; new models and solutions for sustainable and climate-resilient fishery; innovation for sustainability and adaptation of tourism; R&I for climate proofing health systems; expanding the evidence base for climate related health risks and impacts on health system (including mental health).

The expected contributions of R&I to the specific challenges covered by the mission are listed in Figure 6. This list should not be considered as exhaustive and includes issues that are better tackled at national or EU levels. Four points can be made about the contribution of R&I to the mission:

- R&I is needed to support the mission's goal at all TRL levels, from fundamental research on the impact of anthropogenic climate change on planet earth towards innovative large-scale demonstrators for transformative adaptation.

- A broad mix of scientific disciplines is needed from earth and natural sciences to engineering, behavioural and political sciences, as well as trans-disciplinarity as a mode of conducting research. A variety of sources of knowledge is needed including knowledge held by non-research actors such as water agencies or nature conservation bodies, staff in the regional and local authorities, citizens, etc.

- Action research and programming by the regions and large cities are relevant modalities for research to serve the mission's goal.

- The Horizon Europe mission calls projects cannot cover all these needs: the mission has to tap into and link with R&I projects carried out under other programmes of Horizon Europe (such as Cluster 5 under Pillar 2 which is funding lower TRL research and projects on the role of citizens in science) or other sources, and from other programmes supporting the development of innovative digital tools (e.g. for early warning systems) or business models (for adaptation finance), etc.

2.2.2. Developments influencing the mission area

This section addresses the question of the potential need for change in the definition of the mission area, given identified trends. The evidence indicates that the Mission CCA area is broad enough to cover needs and adjust to new/emerging or previously unforeseen/identified factors or trends that are or are likely to impact this mission area. Interviewees and the literature converge to confirm that the key challenges have been well captured in the definition of the mission area and its scope.

"The definition of the mission area is broad enough to stand the test of time, even if there is a lot of uncertainty associated to CC and CC impacts." (an interviewee)

The sustainable development goals (SDGs) are one means to assess developments. Monitoring of the SDG 13: Climate action[9] indicates that the climate-related economic losses trend is worsening, while the commitment to climate actions by local authorities is growing. The latter point is confirmed in a recent overview by the EEA (EEA, 2022). This is likely to reinforce the relevance of the mission without requiring a re-definition of the mission area.

The mission board carried out work (in 2019 and 2020) to capture recent trends. The only new element is the recent IPCC report (IPCC, 2022) which confirms the urgency of climate adaptation efforts at global and EU levels (Figure 7): this points to the need to implement the mission fast and effectively, rather than engaging in a re-discussion of its scope.

[9] In particular target 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

Type of factor/trend	Short summary of the expected impact of the factor/trend
Frequency and severity of occurrence of extreme climatic events Occurrence of new hazards due to combination and cascading effects of multiple risks	"*Widespread, pervasive impacts to ecosystems, people, settlements, and infrastructure have resulted from observed increases in the frequency and intensity of climate and weather extremes, including hot extremes on land and in the ocean, heavy precipitation events, drought and fire weather (high confidence). Increasingly since AR5, these observed impacts have been attributed to human-induced climate change particularly through increased frequency and severity of extreme events.*" (IPCC, 2022) "*Climate change impacts and risks are becoming increasingly complex and more difficult to manage. Multiple climate hazards will occur simultaneously, and multiple climatic and non-climatic risks will interact, resulting in compounding overall risk and risks cascading across sectors and regions. Some responses to climate change result in new impacts and risks*." (IPCC, 2022)
Extent and effectiveness of climate mitigation efforts and impacts	If mitigation efforts are insufficient, systems and territories will have reached hard limits, i.e. points where adaptation efforts are not effective anymore. *"Soft limits to some human adaptation have been reached, but can be overcome by addressing a range of constraints, primarily financial, governance, institutional and policy constraints (high confidence). Hard limits to adaptation have been reached in some ecosystems (high confidence). With increasing global warming, losses and damages will increase and additional human and natural systems will reach adaptation limits (high confidence)."* (IPCC, 2022)
Regulations covering mainstreaming adaptation in sectoral policies	Strengthening regulations to incorporate adaptation in infrastructure planning, disaster emergency management procedures, health system configurations, etc. can reveal new needs in terms of R&I and support faster and deeper mission delivery.

Figure 7. Identified main factors or trends influencing the mission area

Source: author based on cited references

2.3. Tackling climate change adaptation: insights from Japan and Iceland

The approach to developing bold CCA initiatives in non-EU countries has been surveyed for two countries with contrasting experience: Japan and Iceland. Japan has a rather deep experience in CCA strategies and is not likely to be heavily influenced by EU approaches, due to distance and differences in context. Iceland has been chosen as an associated neighbouring country, a close observer of EU developments and a newcomer to CCA. The two countries are likely to have developed their own definition of a CCA 'mission area', their own vision of key community systems most affected by climate change and view main trends from another perspective than EU Member States.

The **Japanese** Climate Change Adaptation Act (2018) and Plan (2021)[10], as summarised in Figure 8, cover categories similar to the ones included in the EU's mission scope, with the exception of a category "industrial economic activities, people's lives and urban life", where "conflict risk and other security impacts due to climate change" is highlighted as climate change impact. As with the EU mission, attention is paid to the wide participation of stakeholders and to the role of local authorities and citizens in CCA, as well as to the provision of reliable scientific information combined with support to local governments. In addition, the Japanese strategy has an axis on "international action and businesses" with corresponding actions respectively on "enhancing capacity in developing countries" as well as another covering "promotion of climate change adaptation by business operators, etc. and business activities contribution to climate change adaptation".

Attention to horizontal governance is seen as crucial, as is the case in the EU, with ministries and agencies cooperating closely across the 'seven basic strategies': the Climate Change Promotion Council, chaired and managed (secretariat) by the Minister of Environment, includes top officials from nine other ministries as well as the Cabinet Office, Cabinet Secretariat and Financial Services Agency.

A climate assessment report describing the status and evolution of climate impacts in key sectors is prepared on a 5-yearly basis to provide a policy-relevant evidence base, used for the preparation of the successive plans. Monitoring and evaluating progress on adaptation is included in the Plan, with the use of key performance indicators (KPIs): a set of 37 KPIs follows progress in each sector covered by the strategy and 29 other indicators follow progress in the 'seven basic strategies' crossing sectors. The Climate Change Promotion Council oversees the evolution of KPIs collected through the strategy monitoring system.

While the plan is national, fine-tuned adaptation measures, as well as additional KPIs, have been adopted at local level to reflect territorial specificities. Local authorities have adopted their 'local climate change adaptation plans' and established 'local climate change adaptation centres' aimed at collecting, organising, analysing and providing information on climate change impacts and adaptation at local level. Each region has established a 'regional climate change adaptation council', a forum for cooperation between national branches of government, local authorities, knowledge centres, businesses and citizens.

The Japanese Innovative Technology for Adaptation to Climate Change (ITACC) programme is a mission-oriented policy initiative launched by the Japanese government in 2013 to promote the development and diffusion of innovative technologies for climate adaptation. The programme supports research and development in areas such as disaster prevention and mitigation, water management, and sustainable agriculture. It includes several KPIs to measure the programme's effectiveness in achieving its goals, including patents and other intellectual property rights obtained, collaborations and partnerships established with industry and academia, and technology transfers and commercialisations achieved.

[10] https://www.env.go.jp/content/000081210.pdf

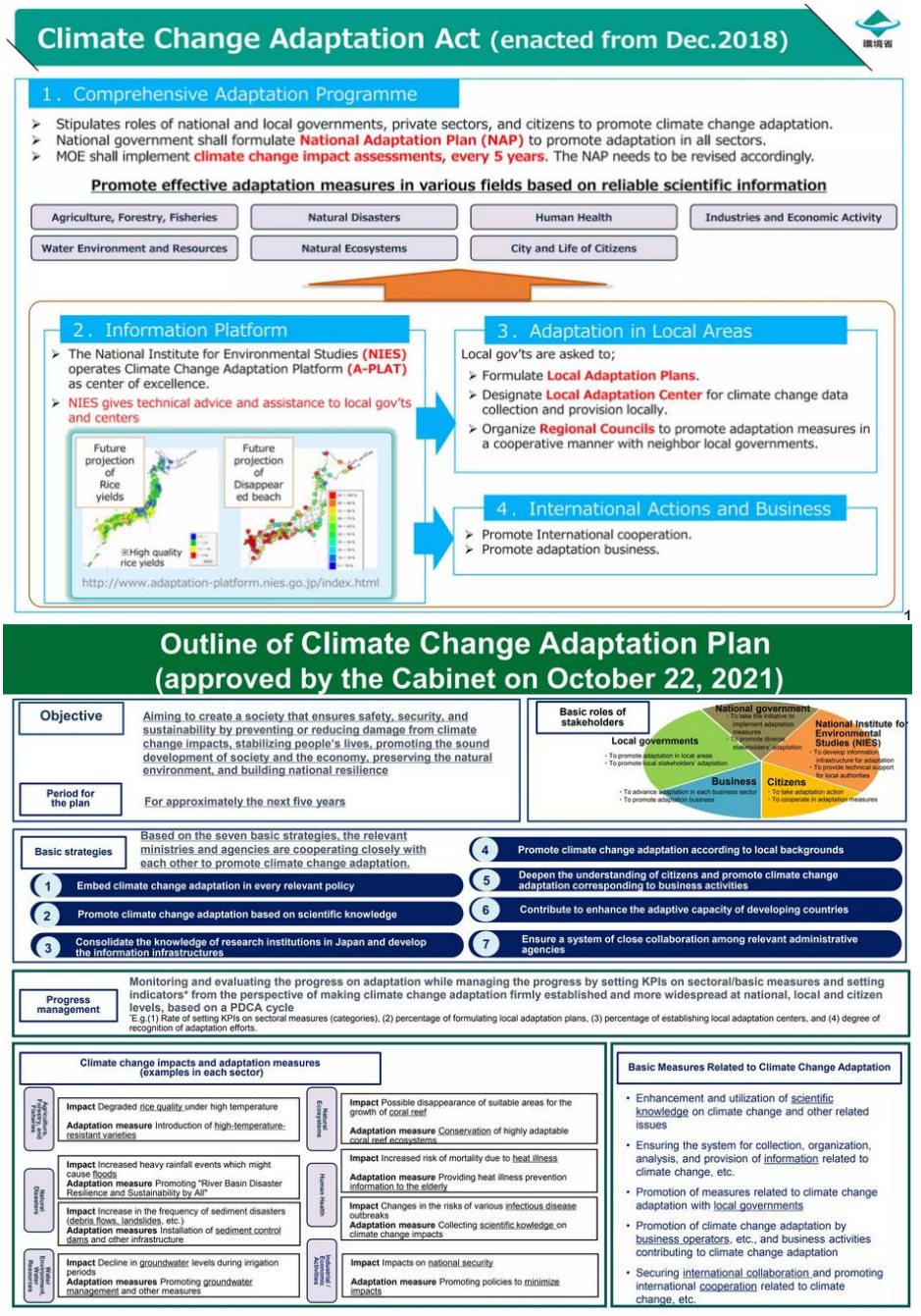

Figure 8. Japanese Adaptation Act and Plan

Source: presentation at OECD fourth meeting of Task force on Climate Change Adaptation[11]

[11] See: https://www.slideshare.net/OECD_ENV/presentation-fourth-meeting-of-the-task-force-on-climate-change-adaptation-yuko-yoshida

To sum up, the Japanese approach to respond to the climate change adaptation challenge has the following characteristics:

- as with the EU mission, it is based on broad consultations with scientists, national and regional authorities, businesses and the wider public;
- cross-governmental cooperation is particularly emphasised, with top level representatives of various ministries and the Cabinet office joining forces to design and follow-up the strategy;
- the regional dimension is seen as important for deploying the strategy, with structures established at that level;
- the production of relevant scientific evidence acts a main building block;
- monitoring is emphasised with the help of a large range of dedicated indicators.

Concerning the CCA scope, the Japanese strategy covers the same elements as the EU mission area, with two additions:

- an explicit focus on international action and notably on enhancing capacity in developing countries;
- a stronger incorporation of business activities.

Considering the extremely high share of renewable energy in final domestic energy consumption[12], and an energy production coming almost entirely from renewable geothermal and hydrological sources, **Iceland** may be regarded as an archetype of a 'green country'. However, while the country has phased out the use of fossil fuels in both electricity production and home-heating, there are still challenges on the road to become carbon-neutral by 2040, as targeted by the Government's 2020 Climate Action Plan[13].

Iceland is a latecomer to CCA: climate mitigation, notably through bold frontrunner pilot experiments on carbon capture and storage, has received more attention than climate adaptation until recently. The country adopted a first CCA strategy in 2021 (Iceland Ministry of Environment and Natural Resources, 2021). The strategy was prepared by the Climate Council, a forum operational since 2018, which gathers a wide variety of stakeholders. The council prioritised placing CCA on the government's agenda and produced a white paper "Preparing for a Better World" to raise attention about CCA. The white paper was open for consultation on the government portal. One of the first findings of the council was that there is a need to foster the use of knowledge for decisions linked to CCA: discussions between scientists and governmental authorities were encouraged through the council's action.

Attention to CCA is growing significantly in Iceland after major landslides events due to heavy rainfalls and ocean acidification resulting in changes in species in the fishing grounds, causing concern for this major national industry. There is a mounting perception that Iceland is more vulnerable to climate change than previously thought, and a report is in preparation

[12] Iceland has phased out the use of fossil fuels in both electricity production and house-heating, so the share of renewable energy in final domestic energy consumption is close to 100%.

[13] See: www.government.is/library/01-Ministries/Ministry-for-The-Environment/201004%20Umhverfisraduneytid%20Adgerdaaaetlun%20EN%20V2.pdf

to assess the country's climate vulnerability. The need for a policy-oriented robust evidence base on CCA and its impacts is seen as crucial. Icelandic stakeholders acknowledge the need to ensure more impact from research, notably through better rewarding impactful policy-relevant scientific contributions by academics, such as contributions to IPCC, and reorienting research towards ecosystems research. A new national knowledge centre on climate change adaptation has been established recently. The new Icelandic strategy on adaptation to climate change features 10 'core values' and 10 'core goals'. In the preface, the Icelandic Minister for Environment and Natural Resources highlights a few major orientations:

- "Adaptation measures will never be better than the knowledge they are based on";
- "We also need to consider mitigation and adaptation co-benefits, since, when they are successful, they can be mutually successful";
- "A key element is that the adaptation of the society to climate change will be just. We must make every effort so that vulnerable groups will not be hit harder by the changes that are made, and also to always make social justice a guiding principle";
- "Local governments and businesses play a vital role in shaping adaptation measures".

The Icelandic strategy is structured in a series of goals covering 15 categories combining key community systems and enabling conditions but does not distinguish between them as the EU mission does. These include: natural hazards, planning, water and sewage, energy, transport, the private sector, fisheries and marine fish farming, agriculture, tourism, insurance and financial activities, public health, national interest, labour market and social infrastructure, coordination of research and information, coordination of efforts to elaborate and implement measures and general goals across societal structures, planning, status assessment and general oversight and evaluation of adaptation efforts.

Summing up, the Icelandic approach to responding to climate change adaptation has the following main characteristics, broadly matching those of the EU Mission CCA:

- an emphasis on the critical importance of building robust evidence and an adequate knowledge base to underpin ambitious CCA strategies aiming at achieving resilience across all sectors of societies;
- the building up of a basis for wide and deep cooperation with stakeholders, including new dialogues between scientists and policy-makers;
- an attention to awareness-raising on CCA (as Iceland is only at incipient stage in rolling out is new CCA strategy), as in the EU mission which takes into consideration the fact that some territories are not yet sufficiently aware nor well prepared on CCA;
- the recognition of a key role for local authorities;
- the need to support the strategy roll-out with indicators, still under development.

Concerning the scope of CCA, Iceland is aiming at broad coverage of key systems as in the EU mission, however key economic sectors of activity (fisheries and tourism) are focused on explicitly as is the incorporation of businesses as a target group. Finally, synergies between mitigation and adaptation are indicated as one explicit orientation in the Icelandic plan, a feature that is more implicit in the EU mission.

2.4. Key lessons from the review of the mission area

There is a large convergence of views, both from interviewees and from literature review, to indicate that **the mission area is fit for purpose and likely to stand the test of time** due to its broad and flexible coverage of key community systems and enabling conditions for resilience. Climate change adaptation is a relatively newer subject than climate change mitigation. This makes the mission area, as such, timely and welcome: it should help push adaptation to the top of policy agendas, in particular of sub-national authorities.

Four features of the mission area are particularly appropriate: 1) a **systemic approach,** fitting the complexity and pervasiveness of climate change impacts, is translated in the choice to focus on five interdependent key community systems; 2) its accent on **social justice and territorial inclusiveness**; 3) the emphasis on the **costs of non-action** that goes hand in hand with its medium- and long-term perspective enshrined in 'transformative pathways'; and 4) an important **role given to sub-national authorities**.

The mission area requires the creation and diffusion of a lot of new knowledge, covering the three objectives of the mission, highlighting **a clear role for R&I to support transformational adaptation, key for the mission's success**. Strong R&I efforts are needed to produce, for instance: better evidence on territorial climate risk profiles and vulnerabilities, impacts of climate-induced hazards, including complex and cascaded impacts; new knowledge and methods on measuring resilience as a positive feature (beyond measuring vulnerability only); R&I activities on new adaptation solutions and models within and across various ecosystems; research and development of suitable models and mechanisms for adaptation finance; inputs from social and political science on effective and inclusive governance models for adaptation opening room for wide participation including citizens, etc. These R&I efforts require transdisciplinary approaches.

Compared to other initiatives in climate change adaptation in Iceland and Japan, the EU mission appears to place **less emphasis on 1) the business dimension and 2) international cooperation**. Moreover, **the linkages between mitigation and adaptation might possibly be further integrated in the mission**, taking notably into account the fact that many authorities have common governance bodies and/or common strategies and plans covering the two complementary directions, and that the search for synergies might help identify actions and initiatives with high co-benefits. This is notably a feature of the new Icelandic CCA strategy.

The quest for **effective governance mechanisms to enhance horizontal coordination** across EC DGs, which is part of the EU mission model, matches the willingness of Japanese authorities to establish cross-ministerial mechanisms, involving senior people from various ministries as well as the cabinet office of the Prime Minister. Another match with an important EU mission feature comes from Iceland, a newcomer in CCA, which integrates an **awareness-raising dimension** in its CCA strategy, also prominent in the EU mission.

3. Mission Area: Cancer

3.1. The scope and definition of the mission area

Europeans are living longer and healthier lives, thanks, notably, to big advances in medical treatment. However, Europeans are disproportionately affected by cancer,[14] which apart from wrecking lives and families, places a major pressure on national health systems. The term 'cancer' covers more than 200 diseases linked to the uncontrolled growth and spread of abnormal body cells that divide uncontrollably and infiltrate and destroy normal body tissue.

The discussion on cancer as a potential mission focus started under Carlos Moedas, Commissioner for Research, Innovation and Science (2014-2019). In 2019, as part of the European Parliament election campaign the European People's Party chairman, Manfred Weber, proposed a "European Masterplan to join our forces to fight against cancer". In response, the new European Commission President Ursula von der Leyen announced a "European Plan to fight cancer to support Member States in improving cancer control and care" as a key component of her political guidelines for 2019-2024. At the World Health Summit 2020 President von der Leyen called for a stronger European Health Union.[15] This was a marked change to the previous position of the Commission which regarded health as a national competence. The COVID-19 pandemic underlined that collaboration in addressing a major health crisis is essential. Stella Kyriakides, the Health and Food Safety Commissioner, was tasked to develop an ambitious plan for cancer. Recognising the increasing number of cancer cases in Europe and the importance of care, the EU developed the Europe's Beating Cancer Plan (EBCP) and the EU Cancer Mission.

Although no information is publicly available about what evidence and methods were used to define and select the mission area for inclusion in the Horizon Europe Regulation, the choice of cancer as a mission area is logical. Cancer is a growing challenge for Europe (EC, DG RTD 2020)[16]. It is the second cause of death in Europe after cardiovascular diseases and the first cause of death by disease in children older than one year. Moreover, cancer is the leading cause of male deaths in an increasing number of Member States. In 2020, there were almost 4 million new cases in Europe and 2 million deaths (A *Lancet* Oncology Commission, 2022). With less than 10% of the world's population, Europe has close a quarter of all cancer cases (Bray et al, 2018). In 2022, the WHO[17] estimated the number of new cases in Europe to be about 4.4 million (or 22.8% of the global number of cancer cases) and the number of deaths at about 2 million (or roughly 20% of the global deaths from cancer). Although there is a slight reduction in mortality due to screening campaigns and improved diagnostics and treatment, the number of diagnosed cases is still increasing and. the number of cancer cases is predicted to increase by 25% by 2035 if things stay unchanged.[18]

[14] See: https://joint-research-centre.ec.europa.eu/jrc-news/cancer-europe-5-things-data-tells-us-2022-01-13_en

[15] https://ec.europa.eu/commission/presscorner/detail/en/speech_20_1983

[16] See: https://cancer-code-europe.iarc.fr/index.php/en/about-cancer/what-causes-cancer and https://gco.iarc.fr

[17] WHO, International Agency for Research on Cancer. The global cancer observatory.

[18] The latest information on cancer statistics in the EU can be viewed on the ECIS – European Cancer Information System.

3.2. Review of the mission area

3.2.1. The role of R&I in addressing the challenges

As stated in the 2022 science, research and innovation performance (SRIP) report: "R&I have the potential to produce novel solutions in areas like health, …" (EC, 2022, p.5). R&I plays a fundamental role in addressing the challenges along the whole cancer control pathway, from prevention to end-of-life care or survivorship, and for improving cancer outcomes.

Within the topic of understanding cancer, Europe (i.e. larger than just the EU27) is a global leader in cancer discovery science with strength lying in molecular, cellular and structural cancer biology; modelling; diagnostic and early detection; new medical technologies and personalised treatments; precision oncology; vaccines, immunotherapies, and drug- antibody conjugates; and paradigmatic shifts in neoadjuvant therapy, especially for immunotherapy (The *Lancet* Oncology Commission, 2022). This strength can be used further to investigate certain types of cancer (e.g. lung cancer) which are researched less compared to other types and relative to its disease burden. Many cases of particular types of cancer can be prevented, yet **cancer prevention research is not sufficiently funded given its potential role in cancer control** (Toumazis et al. 2021). When it comes to treatment, survivorship is still far higher in northern and western countries, although the expectations were that when many central and eastern European countries joined the EU in 2004, they would improve their performance in cancer statistics (incidence, mortality, overall survival). Even within countries access to care is not equal and a 'postcode lottery' to accessing the best care is present (The *Lancet* Oncology Commission, 2022). More efforts on the research side needs to be made to level the playing field. Moreover, the ability to convert research discovery into therapeutic innovation is hindered by regulatory and implementation constraints, and scale-up challenges (Aggarwal et al., 2022). Finally, on the access to cancer control and care, research can / does play and important role too. There are geographical disparities across and within the European countries in access to and delivery of optimal cancer control.

The EU has long prioritised investments in cancer research in order to improve quality of life. Yet, observations from the literature presented in this chapter demonstrate that several issues may still hamper the successful achievement of the Cancer Mission. European programmes supporting R&I, such as Horizon Europe, are rooted in the approach of building a critical mass of research 'champions' in given fields (e.g. medicine or pharmaceuticals) to increase the potential outcomes of research efforts and the returns of public efforts. Yet, for some time, and more recently in the specific case of cancer research (Rekers & Hansen, 2015, Smye and Gatenby, 2022, Rezaei, 2023), the research community has emphasised the need for more interdisciplinarity in research intensive fields, such as cancer, and for greater emphasis on the geographical dimension of collaborations. Interdisciplinarity, intended as the collaboration between agents from different scientific disciplines, is believed to stimulate the exchange of and creating knowledge between fields and create new knowledge at the boundaries (Lyall et al., 2013). As stressed in Smye and Gatenby (2022), *"Promotion of interdisciplinarity is an increasingly prominent element of the strategies promoted by major cancer research funders—no aspect of cancer is entirely within the domain of a single specialism"*. Therefore, big steps have already been made in terms of interdisciplinarity and many lessons have been learned from collaborations (e.g. the contribution of maths and physics to the study of the growth of mass tumours). Yet, the recent improvements delivered by better (and interdisciplinary) cancer research points to the need for even more interdisciplinarity. For example, this is evident in the ongoing demographic

changes in cancer research and care.[19] While the decline in the mortality rate is a promising trend, it is increasing the average age of the population, and changing the prevalence of specific cancers in different contexts. Older adulthood is associated disproportionally with the incidence of common cancers and cancer care and screening systems need to evolve to adapt to take into account these changes.

Geographical proximity among research performers specialising in different fields has many advantages. Evidence from Sweden shows that proximity: "*…allows for frequent opportunities to interact in planned and unplanned settings, and it supports the development of trustful relationships. Partners learn from sharing apparatus, samples and data analyses; they learn from observing each other; and they learn by asking questions in the corridor two weeks following a seminar, and from being asked such questions*" (Rekers & Hansen, 2015). This seems to highlight that sponsoring excellence is probably only partially effective an approach in dealing with cancer.

In this respect, it is a shared opinion in the recent literature that inequity of research and development (R&D) activity differs across R&D stages and between rare and non-rare cancers, with a disproportionate focus on low-need non-rare cancers (Barrenho et al., 2022). Disparities in cancer research areas and care are found also across different ethnic groups and income levels especially, but not just, in the USA (Brown et al., 2014; Lor, 2018; Rubino et al., 2022; Kalarivayil and Desai, 2020).

Another relevant issue concerns a need to increase health policy research. Cancer and in general all non-communicable diseases (NCDs) represent the major cause of death in Europe. It, thus, increasingly becomes connected to and affects many other aspects of human life and, therefore, calls for changes in health policy (Wepner & Giesecke, 2018). R&I funding priorities can have a drastic impact on extending human life. However, contrasting cancer and other NCDs will require intervention in other societal fields, with different timelines and what could work today (e.g. nutrition and cancer) might require further intervention in the future. Social studies have often focused on how policy can shape the medical domain, fixing priorities and relevant fields of research, especially in resource intensive fields such as medicine (Cambrosio et al., 2022). Therefore, policy will determine and shape these scientific fields. In this respect, some researchers share concerns regarding the mission-oriented approach gaining consensus in Europe and the US (The White House, 2022), aiming at reducing cancer mortality (Steward et al., 2023). Even in this case, the authors underline the fundamental necessity to match technoscientific aspects to socio-economic and cultural changes to achieve these goals. Cancer policy design should be based on the consultation of a wide audience of physicians, sociologists, behavioural experts and also the general public. In the framework of the transformative innovation literature, the authors propose "*that a network model of systemic innovation should be initiated for ongoing iterations of cancer policies, with strong interactions within a broader group of experts who will not only define policy goals but also address their modes of implementation"* (Steward et al., 2023). This is envisaged in the governance of the Cancer Mission (as discussed in the Mission Assessment Report).

Moreover, healthcare research in fields such as cancer is shifting towards a much greater reliance on biotechnology, nanomedicine and bioinformatics. These changes are bringing great scientific advancements but have the downside of polarising research focus towards specific types of cancer and limiting the international contribution of researchers in lower income countries (Kalarivayil & Desai, 2020). In other words, research in rich countries will concentrate on these types of cancer most affecting their citizens, limiting the collaboration

[19] https://cancercontrol.cancer.gov/research-emphasis/supplement/cancer-and-aging

opportunities with those researchers from developing countries investigating other types of cancer and still using more established methodologies and approaches. This is particularly worrying if the current negative relationship between cancer mortality rates and educational and economic levels, even in countries with a long-established tradition of equitable welfare and social justice, is considered (Frederiksen et al., 2022).

Screening and prevention remain big challenges in controlling cancer in Europe as in other contexts such as the USA (Reihani et al., 2021). Patient education, communication and distrust in health systems continue to represent major barriers to cancer screening and to controlling the disease and data collection. The need for better communication extends far beyond R&I on cancer, demanding better information on – as well as research – into the effects of environmental regulations (e.g. on the impact of chemicals on health) and a better involvement of research institutions in scientific communication (Kourany & Fernández Pinto, 2018).

Finally, Specific events of the last few years (COVID-19, Brexit and the Russian invasion of Ukraine) provide example of the fragility of health care systems that can come under pressure from external or unexpected events. The short-term effects may be most visible, but the impact of such events can last much longer, a phenomenon which is being termed the COVID decade (The *Lancet* Oncology Commission). R&I can be of assistance here too investigating effects of the catastrophic events on the health care systems, changes needed to be introduced in the system not only in terms of care but also prevention and looking into innovative approaches. For example, during the COVID-19 outbreak in Sweden when non-emergency health care stopped leading to the postponement of cervical screening, a temporary government regulation allowed primary self-sampling with HPV screening in all ages. The crisis made the health care system adapt (WHO, 2022).

In another example, at the end of 2021, Britain had 4,285 fewer European doctors than if the numbers of those who were immigrating before the Brexit vote in 2016 had been maintained (McCarey and Dayan, 2022). This drop affected the amount of surgery that can take place (due to shortages of both anaesthetists and certain types of surgeons). Although no specific analysis was conducted in relation to specific types of diseases, it is safe to assume that a shortage of anaesthetists will impact surgical procedures linked to cancer. In this respect, links between education and health systems can be important as well as wrong choices might have long-term consequences on the healthcare workforce Uncovering shortages of skilled labour related to cancer prevention, treatment and care may lead to a re-think of education and training policies. In addition to the results from the literature review,

Specific challenges	Expected contribution of R&I (examples)
Prevention (implementation of the screening regulations)	Understanding human behaviour when it comes to prevention
Need or emergence of new treatment protocols and methods	Academic-led clinical trials, translation of research into clinical practice, new therapeutics
Guaranteeing good quality of life for cancer survivors	Understanding and addressing physical, psychosocial, financial needs of cancer survivors
Geographical disparities across and within the European countries in access to and delivery of optimal cancer control	Cancer research strengths at the moment are not evenly distributed across the countries and do not always align with the cancer priorities of individual countries.

Specific challenges	Expected contribution of R&I (examples)
Catastrophic events affecting the resilience of the health system	Understand the effects of the catastrophic events, finding solution to be able to prepare for them

Figure 9 table below sums up a number of expected contributions of R&I to addressing the mission area challenges.

Specific challenges	Expected contribution of R&I (examples)
Prevention (implementation of the screening regulations)	Understanding human behaviour when it comes to prevention
Need or emergence of new treatment protocols and methods	Academic-led clinical trials, translation of research into clinical practice, new therapeutics
Guaranteeing good quality of life for cancer survivors	Understanding and addressing physical, psychosocial, financial needs of cancer survivors
Geographical disparities across and within the European countries in access to and delivery of optimal cancer control	Cancer research strengths at the moment are not evenly distributed across the countries and do not always align with the cancer priorities of individual countries.
Catastrophic events affecting the resilience of the health system	Understand the effects of the catastrophic events, finding solution to be able to prepare for them

Figure 9. Expected contribution of R&I to addressing the mission area challenges

Source: authors based on multiple references cited in the text.

3.2.2. Developments influencing the mission area

As it has only been a few years since the mission area was defined, the importance of cancer as a mission area is unlikely to have changed significantly. One way to assess this is by looking at the changes and forecasts for statistics around cancer as well as at developments in the societal challenges the mission area relates to. For the former the WHO data is a solid foundation; for the latter the EUROSTAT dashboard that monitors progress towards the SDG targets can be used. WHO predicts that cancer cases are predicted to increase in Europe; the number of new cancer cases will be 5.32 million by 2040 (or a 21% increase compared to 2020) and the number of deaths will increase by 0.6 million to 2.53 million deaths (see Figure 10 and Figure 11).

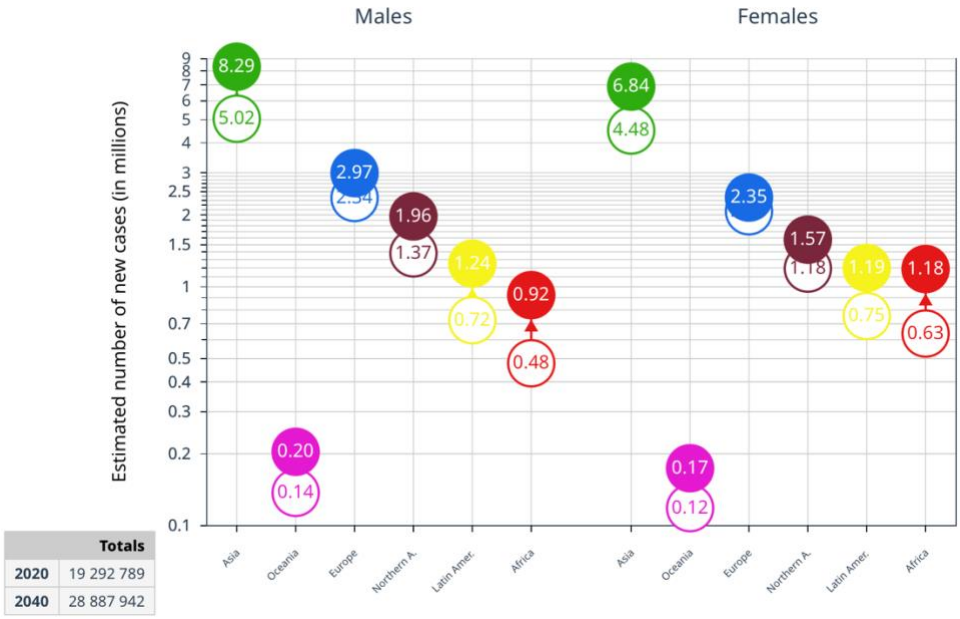

Figure 10. Estimated number of new cases from 2020 to 2040, Males and Females, age [0-85+]

Source: Cancer Tomorrow |IARC, data version: 2020, accessed 23 March 2023, https://gco.iarc.fr

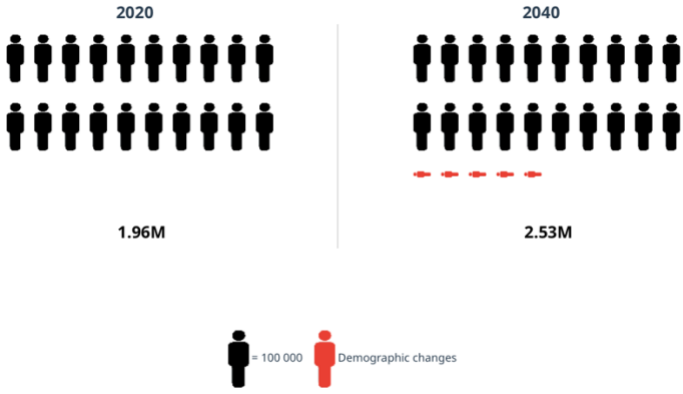

Figure 11. Estimated number of deaths in Europe from 2020 to 2040, both sexes, age [0-85+]

Source: Cancer Tomorrow |IARC, data version: 2020, accessed 23 March 2023, https://gco.iarc.fr

The major causes of cancer, although well-identified in the literature, are not yet adequately addressed. For the SDG 3 on good health and well-being, while performance on reducing smoking in Europe is positive, for obesity, another major cause of cancer, the EU is moving away from the target on obesity rates[20]. Obesity is both a NCD and a fundamental driver of many other diseases (e.g. type 2 diabetes and cancer). Obesity is at the heart of achieving the SDG target on NCDs "By 2030, reduce by one-third premature mortality from NCDs

[20] See: https://ec.europa.eu/eurostat/web/sdi/key-findings

through prevention and treatment and promote mental health and well-being". Progress towards other SDGs is also important for Cancer Mission.

One of the targets in SDG 6 "Ensure availability and sustainable management of water and sanitation for all" is on nitrate in groundwater. The nitrate concentration in groundwater has increased in recent years. Currently, the average concentration remains within EU drinking-water standards (50 mg/L) [21], but hotspots (e.g. Malta, Cyprus, Belgium and Germany) exist where the nitrate concentration is above the norm (Eurostat, 2022). If drinking water quality control is not performed effectively, excess nitrate is absorbed in the body through drinking groundwater. Nitrate when converted into nitrite in the human body induces certain diseases, such as infant methemoglobinemia and cancer (Feng et al., 2020) and increases the risk of colorectal cancer when transformed into carcinogenic *N*-nitroso compounds (Schullehner et al., 2018). Considering the progress towards SDG 13 "Take urgent action to combat climate change and its impacts", insufficient progress towards the EU target for average CO2 emissions from new passenger cars contributes to air pollution. The latter is one of the causes of cancer[22]. The progress on these indicators indicates that at least in several respects, that there is still reason to keep investing in cancer mission area.

There are also several other concerning developments – unforeseen but rather catastrophic – which keep the relevance of cancer area even more on the agenda. To deal with the effects of both events, a systemic and transformative solution is needed that mission ensures. The COVID-19 pandemic put significant pressure on national health systems and further crystalised the cancer situation. For example, there was a 25% drop in cancer diagnoses in the Netherlands and a 50% delay in treatments in the UK, suspended prevention and early detection programmes (EC, DG RTD 2020). According to the collected evidence, during the pandemic, about 1 million cancer diagnoses might have been missed (Lawler & Crul, 2022). The pandemic stressed all sectors in the global economy, incl. healthcare and research. It negatively affected cancer research leading to the substantial reductions in cancer clinical trials, disruption to discovery cancer research, and reductions in cancer research funding (Freeman et al., 2022). Most of the non-COVID related research (including cancer research) was scaled down and there is a risk that funding for research at the national level as well as private donations / investments will decrease in the near future (EC, DG RTD 2020).

At the time the mission was defined, there was not yet a war in Ukraine. Since the invasion of Ukraine by Russia (on 24 February 2022) it has become one of the major challenges in Europe and had a major effect on the cancer control adding further to the pressures the health systems accumulated during the COVID-19 pandemic. Treatment and care were disrupted, some oncology units were closed, those that continued working abandoned less urgent procedures, and preventive measures, such as screening programmes, were paused (The *Lancet* Oncology Commission, 2022). Many of the patients moved to other countries for treatment and care. Poland was the country that has probably received the largest number of patients. The government quickly announced that all the Ukrainian refugees have the right to receive the same health care as Polish citizens and Ukrainian patients were given an opportunity to connect to more than 20 oncology centres (McIntyre, 2022). The European response to war by welcoming refugees (incl. patients) have increased the costs of the national health systems. Yet, there is also another negative effect of war on cancer. Both Ukraine and Russia were two of the largest contributors to clinical cancer research in the world, especially industry-focused clinical research. At the start of the war Ukraine had 245 active pharmaceutical cancer clinical trials, with 127 trials that were actively recruiting (The

[21] https://ec.europa.eu/eurostat/cache/metadata/en/sdg_06_40_esmsip2.htm

[22] https://www.eea.europa.eu/highlights/pollution-and-cancer

Lancet Oncology Commission, 2022). With the trials stopped or put on hold will bring delays into the development of new treatment.

In addition to the literature review results, Figure 12 sums up some factors or possible trends influencing the mission area also bringing insights collected during the interviews.

Type of factor/trend	Short summary of the expected impact of the factor/trend
Economic: workforce crises, need for competence development	If insufficient workforce available in prevention, health care, and nursing, this will create bottlenecks in cancer treatment and care and could potentially increase cancer cases
Geopolitical: refugees crises due to wars and climate change	Increasing pressure on the healthcare systems of the countries accepting refugees. Equality of access to care and treatment will become higher on the health agenda.
Policy: the need to share data and opportunities offered by the European Health Data Space (EHDS)	Potential positive effect on cancer research and treatment. Individual having control over their health data could support them in seeking faster cancer treatment across the border.
Policy: new directive from EMA regulating clinical trials, new directive on medical devices	Potential to influence the speed of introduction of medical innovation to market / healthcare system. This in its turn will improve cancer diagnostics and treatment
Scientific: more cancers becoming rare cancers	More basic research might be needed to understand new types of rare cancer and how to treat them.
Scientific: cancer becoming more and more a chronic disease	Reforms in the health and care system might be needed to cope with the long-term nature of the disease. Quality of Life will become higher on the agenda.
Social: major needs for quality of life and survivorship (e.g. tertiary prevention)	Reforms in the care system might be needed.
Technological: use of AI/machine learning cancer diagnostics, radiology, new technologies for screening	Cancer cases identified faster, thus increasing the likelihood of survivorship. AI-driven imaging help improve consistency and reduce workload. Screening in itself could contribute to changing people's attitudes towards cancer and becoming more active in prevention.

Figure 12. Identified factors or possible trends influencing the mission area (in alphabetical by type of factor)

Source: authors based on interviews and literature review

3.3. Tackling cancer: insights from the USA

The USA is an example of how cancer has been tackled strategically on the national policy agenda over a long period of time (since the 1970s), with varying levels of success and resulting in numerous modifications. As early as the 1970s, President Nixon declared the 'War on Cancer' with the National Cancer Act of 1971, and it was led by the National Cancer

Institute (NCI). The law was put in place to strengthen the NCI and it was described as an "effort to find a cure for cancer". In 2003, the then NCI director proposed a challenge to eliminate the suffering and death due to cancer by 2015 (Eschenbach, 2005). Not all actors were convinced that this mission was possible. In March 2009 the US Senate issued a new bill to replace the 1971 National Cancer Act so as to modernise cancer research, increase prevention, provide cancer treatment and survivorship initiatives (GovTrack.us, 2009). During the 2008 presidential campaign Barack Obama and Joe Biden published a plan to combat cancer. The focus was on doubling the federal funding for research (basically supporting the National Institute of Health and NCI) and to strengthen efforts to increase funding for the Food and Drug Administration. President Obama's 2009 economic stimulus package included USD10 billion for the NIH. Despite all the efforts (mostly funding and strengthening research organisations) put together, the 'War on Cancer' ended up as *"a textbook exemplar of hubris and disappointment with little impact on the overall trajectory of cancer deaths"* (Steward et al., 2023).

In 2016, the Cancer Moonshot was introduced to deal with that disappointment and take a broader approach on the cancer topic. Then Vice President Biden stated that *"the cancer system of the 20th Century must be reimagined for the 21st Century"* and that "*too often our cancer culture and system plays by the rules of '71" (Ambrose, 2016)*. The overarching goal for the Cancer Moonshot was different from the 'War on Cancer' ambition and focused on significantly reducing mortality from cancer looking at the whole disease pathway from prevention to care. Priorities of the Moonshot were elaborated by a 'Blue Ribbon Panel' through 10 recommendations. Nine of them reference 'therapy', 'inhibitors' or 'treatments'. Recommendations with therapeutic approaches relied heavily on genome sequencing. It was perhaps not surprising to see so many linkages to therapeutic solutions given that the panel was constituted by academic leaders in oncology and basic cancer research as well as representatives from the pharmaceutical and biotechnology industry. Technology experts (from Google, Amazon, Sage and Microsoft) contributed (Steward et al., 2023). In February 2022, the Moonshot was relaunched[23] by President Biden as Moonshot 2.0 as part of the new focus of the White House Office of Science and Technology Policy on innovation policy. The goal is now to *"cut the death rate from cancer by at least 50% over the next 25 years and improve the experience of people and their families living with and surviving cancer" (*The White House, 2022).

Moonshot 2.0 builds on the 2017 *Lancet Oncology* Commission and is still very much technoscientific but it goes beyond the bioscience/oncology community. This new plan calls for a "cancer Cabinet" bringing political leadership from the White House Office of Science and Technology Policy. It has representatives from different federal departments and agencies bringing 'all-of-government approach' (Carnival, 2022), for example, by also including the Departments of Commerce and Labor, the National Aeronautics and Space Administration, and the White House Gender Policy Council. Community Health Workers got engaged through the Cancer Panel's "Closing gaps in cancer screening' (President's Cancer Panel, 2022). The Cancer Cabinet has five priorities: (1) close the screening gap; (2) understand and address environmental exposure; (3) decrease the impact of preventable cancers; (4) bring cutting edge research through the pipeline to patients and communities; and (5) support patients and caregivers (The White House, 2022b). The main change between the 2016 Moonshot and Moonshot 2.0 is not solely on what should be achieved but how to do in the community. There has been a move away from a purely technoscientific to a more socio-economic and even cultural approach.

[23] The 2016 Cancer Moonshot was terminated by President Trump.

The EU Cancer Mission was announced at a similar time as Moonshot 2.0. In its selection and design (see the mission assessment report) it does seem to be avoiding the major technoscientific traps for a mission bringing a larger community into the activities and putting citizens and patients in the centre. A European response to the USA policies was published as the *Lancet Oncology* Commission "The European Groundshot" in November 2022. Its authors state that *"although the high-tech science that is supported by the Cancer Moonshot initiative might set new standards and programmes to benefit some patients…a parallel cancer groundshot is needed to improve the lives of patients with cancer today and in the next two decades"* (The *Lancet* Oncology Commission, 2022). Some researchers (Steward et al., 2023) believe that the mission can go even further, as, although the authorship of the 2022 *Lancet* Oncology Commission is much wider compared to the 2017 USA Commission, it does not necessarily capture all needed actors. Among additional actors, experts in health policy, health economics, behavioural scientists are mentioned to contribute to the implementation of prevention and early detection. This can go even further by including other experts who could contribute along the cancer disease pathway from prevention to care and in ensuring the quality of life and equality in access to care. Such additional steps and a move towards a socio-technical (rather than just technoscientific) policy is visible in the UK Cancer Research programme "Early Detection and Diagnosis of Cancer – A Roadmap to the Future, 2020" (Cancer Research UK, 2020).

3.4. Key lessons from the review of the mission area

Pressures to deal with cancer are not going away and almost all the factors point in this direction. Some factors, of course, will affect positively the cancer area, such as, for example, technological developments enabling the application of AI for cancer diagnostics. It is unlikely that scientific and technological breakthroughs will, in the near future, make the mission area less relevant. This is due to two fundamental aspects. First, cancer is not one disease with one cause but several diseases with their separate trajectories. When discussing 'cancer' as a mission area it is important to keep in mind that the key discoveries in the 1980s brought breakthroughs in understanding the cancerous process as occurring at the molecular level. This transition means that cancer is not viewed any longer as one organ-based disease, one diagnostic procedure and one treatment all in the same hospital but a combination of diagnostic approaches, medical interventions and of several therapeutic modalities. This means that the participation of experts from more than one hospital or healthcare service is needed. As more types of cancer are identified this calls for new research into the understanding of cancer and finding suitable diagnostics and treatment methods.

Second, what is critical is the cancer care pathway – from prevention to care – which regardless of the disease has the same elements (see Figure 13). It is crucial to tackle cancer systematically from prevention to survivorship and quality of life, which implies activities should span much wider and beyond just R&I. Emerging technologies might bring solutions to different elements of the cancer care pathway, but they will not solve them all. For example, the numbers of cases of cancer might rise because the technologies will allow better identification of cancer. This will then need further decisions and solutions on what to do with these cases and how the treatment and/or care parts of the pathway need to be adjusted. Translation research might lead to new and more powerful treatment options. This could influence the recovery and survivorship, which in their turn might need to be adjusted. To take new scientific and technological solutions as well as new care protocols into practice require specialists, not only cancer diagnostics and treatment specialists but also, for example, psychologists, care workers etc. This requires education, training and career development. To organise the overall structure to manage various activities needs policy decisions around funding mechanisms, addressing ethical issues, and organising the science. This can be achieved by addressing the topic through a mission-oriented approach.

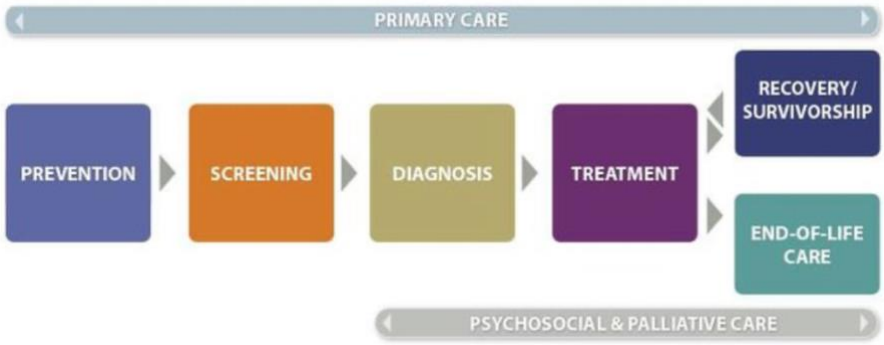

Figure 13. The cancer journey

Source: Rubin, G., et al (2015)

This multiplicity of meaning behind one word 'cancer' does show that there is sufficient flexibility built into the mission area definition. This is the overall impression coming from the desk research and the interviews. The mission area is defined in a focused manner (i.e. cancer sounds very concrete and targeted) but yet wide enough (i.e. cancer is not one disease but a multiple disease[24], the pathway of the disease has multiple elements). The scoping as well as developments of the disease make it unlikely that the mission area will become irrelevant. In sum, there are no findings to suggest the adjustments to the mission area. However, two elements need to be kept in mind and acted on:

1. **Taking into account the time needed for impacts of certain interventions to materialise when designing monitoring framework:** Most of the preventive activities linked to changes in the lifestyle will give results far beyond 2030. Applying very rigid monitoring approach linked to specific hard indicators could indicate that little is coming out of the activities around prevention. The temptation will be to pay less attention to this element of the pathway, to invest less, to even stop. This would be an erroneous decision. The comprehensive approach to achieving the mission goal is to keep the whole pathway intact but acknowledge that the outcomes and impacts from different activities could take time. This observation is important to take onboard when designing a monitoring framework for the EU missions.

2. **Building a new mission-oriented ecosystem requires changes in how different organisations operate.** To bring transformative changes to any system, such a system needs to be disrupted. Here a system innovations approach is needed to build a new ecosystem. Focusing just on research and technology-based innovations will not be enough. Social innovation is needed too, whether it is around the creation of a new health economic model or in changing how the organisations in the cancer ecosystems are run. For that new actors as well as roles might be needed. This could be, for example, experts with social sciences and / or humanities background. They are included in some mission-related activities, but this tends to be linked to the prevention part of the cancer care pathway, i.e. to understand why humans do things they do or do not. However, the social sciences expertise is also needed to help organisations involved in delivering on the mission change and adopt a transformative mindset needed for the mission to succeed.

[24] See: https://www.who.int/health-topics/cancer#tab=tab_1

4. Mission area: healthy oceans, seas, coastal and inland waters., seas, coastal and inland waters.

4.1. The scope and definition of the mission area

The ocean, seas, and coastal and inland waters are elements of the water-cycle continuum, on which all planetary forms of life depend upon, including humans. The hydrosphere is a climate regulator, dominating the planetary carbon, water and heat budgets: oceans and waters influence climate and weather patterns, provide us with drinking water and protein food. In addition, the planetary waters are also a place of recreation, trade and connectivity for humans. The hydrosphere is, however, seriously endangered. As a result of unsustainable greenhouse gas emissions (GHGs), emission of land and water based pollutants, and of the overexploitation of biological resources and natural ecosystems, the hydrosphere has warmed, become more acidic, less oxygenated, poorer in biological resources and less able to provide services to the human population, in terms of food availability, of drinking-water resources, of resilience to extreme weather conditions and even of tourism, ultimately affecting human well-being.

After a policy debate at European and national level, inspired by the work of Mariana Mazzucato (EC, 2018), in 2019, the European Council and European Parliament proposed five broad mission areas, including '**healthy oceans, seas, coastal and inland waters**', aligned with the principles of a mission-oriented policy that calls for a novel systemic intervention. The mission area provides a frame for a mission that focuses on defining the challenges and scoping the actions to achieve cleaner, healthier, and more resilient aquatic environments, related to the EU's marine and freshwater ecosystems, ensuring their sustainable use and protection. The mission area is also aligned with the broader goals of the European Green Deal and the EU Biodiversity Strategy for 2030. The aim is to contribute to the conservation and sustainable use of aquatic resources, promote ecosystem health and resilience, and ensure the long-term well-being of European aquatic environments and the communities that depend on them.

4.2. Review of the mission area

The mission area of healthy oceans, seas, coastal and inland waters is a multidimensional space influenced by very varied external factors, such as environmental conditions, ecological stressors, societal approaches, political governance, and management. A series of authoritative studies have demonstrated the state of degradation of the water continuum, and provided evidence to define the ocean, seas, and coastal and inland waters as an area for urgent and unabated policy attention and for R&I actions, as summarised in Figure 14.

Specific challenges	Evidence for the specific challenge
Changes in the physical conditions of ocean and seas	• The ocean has warmed unabated since 1970 and has taken up more than 90% of the excess heat in the climate system • Since 1993, the rate of ocean warming has more than doubled • Sea surface temperature yearly warming trends for the European regional seas range from 0.03 to 0.07°C (uncertainty range is less than 10%) • The warming trends, between 1993 and 2017, are evident both in the upper oceanic layer (0-700 m) and middle layer (700-2000 m), and projected to continue to warm in the long-term (by 2100), increasing at a rate of 0.9 ±0.1 Wm-2 in the upper (0-700m) and of 1.2 ±0.1 Wm-2 integrating depth to 2000 m • Sea level continues to rise at a rate of 3.2 ± 0.4 mm year−1. As the ocean warms, its volume expands (thermosteric effect), which is a major cause of global mean sea level rise. The upper ocean (0–700 m) thermosteric sea level has been rising since 1993 at a rate of 1.4 ± 0.1 mm per year • Since 1993, the ocean is losing a sea ice extent of nearly 770,000 km2 per decade, in the northern hemisphere, while the sea ice extent in the southern hemisphere is increasing by 80,000 km2 per decade • Marine heatwaves have doubled in frequency, since 1982, and are increasing in intensity
Changes in the biogeochemical conditions of ocean and seas	• The ocean has taken up between 20-30% of total anthropogenic carbon since the 1980s, a major cause of ocean de-alkalinisation (i.e.: acidification). Open ocean surface pH has declined by a range of 0.017 to 0.027 pH units per decade since the late 1980s • Over the past 30 years, 26% increase in ocean acidity from pre-industrial times is registered, threatening marine life and hampering the ocean's role in moderating climate change • The Ocean is losing oxygen, overall, with a loss between 0.5-3.3%, between 1970 and 2010, from the surface to 1000m with an expansion of the oxygen minimum zones by 3-8%. Primarily this is due to changing ocean stratification, ventilation and biogeochemistry, which reinforce the smaller contribution due to warming-induced reduced solubility of oxygen in seawater • Chlorophyll-a, the main photosynthetic pigment contained in all phytoplankton, has shown increasing and decreasing trends over the past 19 years (1998-2017). At global scale, chlorophyll-a has been increasing by 0.6± 0.01% per year. The increase of phytoplankton biomass is related both to direct physiological alterations and indirect changing water column stratification and

Specific challenges	Evidence for the specific challenge
	resource availability, mainly nutrients and light. Variability of this phenomenon exists, with regions where this trend has an opposite sign, i.e. Chl-a concentration is decreasing • The extent of marine protected areas has doubled since 2010 • The proportion of marine fish stocks that are within biologically sustainable levels declined from 90% in 1974 to 67% in 2015
Changes in freshwater systems	• Changes in landscapes, growth in food and energy production and the movement of people into urban areas alter the quantity and quality of our freshwater resources. • Hydro-morphological pressures, diffuse pollution and water abstraction have impaired freshwater ecosystems and are reducing the amount of runoff water that reaches the world's oceans. • New infrastructure disrupts the natural flow of rivers and the condition of lakes, while in many places, the level of groundwater is falling, and lakes are drying up. • Today, 65% of global rivers are considered as being under moderate-to- high threat in terms of human water security and biodiversity. Since the beginning of the twentieth century, more than 800.000 dams have been built to facilitate increased withdrawals, and currently 75% of the main rivers are fragmented. Some large river basins have seen their flow reduced by almost 75% over 30 years due to increasing water extraction. • The flows of many rivers are not sufficient to sustain the deltas, the consequences are losses in fish biomass and biodiversity, as well as coastal erosion due to a great decrease of sediment load.
Changes in the socio-economic conditions	• In 2017, atmospheric CO2 concentrations reached 405.5 PPM, representing 146% of pre-industrial levels. To limit global warming to 1.5°C means that global carbon emissions need to fall by a 45% by 2030 from 2010 levels and achieve net zero emissions by 2050. • From 1998 to 2017, climate-related disasters around the world accounted for 77% of the nearly $3 trillion in direct economic losses from disasters, claiming an estimated 1.3 million lives. The biggest challenges are investment in disaster-risk reduction for resilience and promoting policy coherence between the SDGs and climate change. • From 2013–2014 to 2015–2016 a 17% increase in global climate finance is observed, still relatively small in relation to the scale of the problem. Moreover, investments in climate activities are still surpassed by those related to fossil fuels ($781 billion in 2016). • More countries are making plans to boost their resilience and capacity to adapt to climate change, raising the number of parties that ratified or acceded to the Paris Agreement, from the initial 114

Specific challenges	Evidence for the specific challenge
	in 2016 to 186 in 2019, and to 194 states and the EU (as of February 2023), representing over 98% of global greenhouse gas emissions, including China and the United States, the countries with the 1st and 2nd largest CO2 emissions among UNFCCC members.
Ethics	• Unethical behaviour has led an unsustainable human footprint in the use of our water resources and water-related ecosystem services.
Economy	• Losses in the order of €3-20 trillion per year in ecosystem services and of €5.5-10.5 trillion per year due to land degradation. • Almost half a billion people depend at least partially on small-scale fisheries, which account for 90 per cent of employment in fisheries worldwide. • Poor water quality and sanitation, food scarcity, poverty, hunger, unemployment, warfare.
Biodiversity loss	• Nature across most of the globe has now been significantly altered by multiple human drivers, with the great majority of indicators of ecosystems and biodiversity showing rapid decline • Human actions threaten more species with global extinction now than ever before

Figure 14. Specific challenges addressed by the mission area

Sources: IPCC, 2019, United Nations, 2022, Copernicus Marine Service, 2021, NASA Earth Observatory data, Data from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), OECD, 2016

Understanding the complexity of the interconnections between the water system's health, the climate, biodiversity and food provision, is fundamental to develop the required flexible capacity to manage challenges simultaneously, in a systemic perspective. In the following sub-sections the potential contribution of R&I to meeting the mission area challenges is assessed along with the main trends that may influence the mission area.

4.2.1. The role of R&I in addressing the challenges

The development and widespread use of new technologies through R&I activities is crucial to fulfilling the EU ambition to reach net-zero emission by 2050 (European Commission, 2019), as well as to confront many of the challenges identified in this mission area. R&I are acknowledged as indispensable components of the Recovery and Resilience Facility (RRF). Plans developed by Member States include investments supporting the public science base, academia-business cooperation, business innovation and mobilising R&I capacities to accelerate the green and digital transitions and enhance resilience. Given the foci of the mission area, the expected contributions of R&I to address the main specific challenges for healthy oceans, seas, coastal and inland waters are listed in Figure 15.

Specific challenges	Expected contribution of R&I
Restoring nature	• Knowledge and technology for nitrogen cycle restoration • Technologies for removing plastic pollution from water, especially at source • Technologies and nature-based solutions for climate-resilient coastlines • Technologies for water sanitation • Knowledge of the aquatic ecosystem connectivity
Climate Neutrality	• Knowledge and technology for understanding and modelling the nexus hydrosphere-climate • Carbon emission curbing, including new fuels; and: carbon capture/storage, also from nature-based solutions
Clean water	• Technologies and solutions for water sanitation, conservation, filtration, recovery and desalination
Knowledge system	• Digital Twin of the Ocean: A replication of the water system which could support decision taking at times of crises, through environmental forecast systems as well as marine spatial planning tools and knowledge sharing • Open Science practices for data findability, accessibility, interoperability and reuse
Humans at sea	• Ethics (ocean literates, ocean professionals, civil society engagement, citizen science)
Governance	• Coordination and management support actions to ensure multi-party approach

Figure 15. Expected contribution of R&I to addressing the mission area challenges

Source: Authors based on cited reference

Specific topics of R&I that can contribute to addressing the mission area challenges include:

- the interdependencies among the elements of the water-climate nexus, and how this impacts life on Earth is at the core of a fuller understanding of the dynamics of this area and of providing opportunities for intervention, mitigation and adaptation strategies;

- the novel dimension of ocean ethics, as it is expected to produce a cultural shift and behavioural changes at the individual scale, regarding the impact of human activity on the hydrosphere. More R&I is required into ocean ethics which implies the mobilisation of civil society, in order to bring about a shift of behaviours in production of goods and services, as well as an awareness of the inference of daily human-life activities, on the status of our water ecosystems and on the well-being of all forms of life on the planet.

- the use of digital technologies for representing and managing the water continuum are also a rather novel element for possible R&I action, which would support a modern ocean governance and management system.

Moreover, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has issued a work programme (2019-2030) and a scoping report (IPBES, 2021), which provide a framework for an on-going thematic assessment of the interlinkages among biodiversity, water, food and health (nexus assessment).

However, R&I actions have been indicated to only be part of the solution (IEEP, 2022), with a pool of more than 300 experts on the status of the EU Green Deal declaring that their belief in this type of investment will only marginally impact the current relevant trends. The experts indicated that the real game changer is citizens behaviour and recognised the relevance of the mobilisation and engagement of civil society, and the relevance of ethics to support behavioural changes. EU R&I policies thus have a role to play in coordinating the main transition actors: industry, universities, national and regional authorities and civil society.

4.2.2. Developments influencing the mission area

The mission-area-specific factors and trends need to also be considered in the context of the broader challenges faced at the EU as well as the global scale, to review the mission area more fully. Global megatrends can be defined as 'those developments already underway and nearly impossible to change over the coming decade, which will inevitably frame any possible future scenarios'. An up-to-date of the main factors and trends influencing the mission area is provided, to determine what the likely impacts will be for the ocean and water system, and whether a mission in this area remains relevant, from a policy and R&I perspective.

Type of factor/trend	Description	Short summary of the expected impact of the factor/trend
Environmental	• In 2021, more than 17 million metric tons of plastic entered the world's ocean, making up 85% of marine litter. The volume of plastic pollution entering the ocean each year is expected to double or triple by 2040. • The global nitrogen cycle results altered by land-based, human-activity-related emissions, mainly due to agriculture practices of crop fertilization (Battye, 2017), leading to the question whether Nitrogen is the new Carbon and describing it as a major challenge for the new century (Mellilo, 2021). • More than a third (35.4%) of global fish stocks were overfished in 2019, up from 34.2 per cent in 2017 and 10% in 1974. However, the rate of decline has recently slowed.	• Reduction of both water- and land-based ecosystem services

Type of factor/trend	Description	Short summary of the expected impact of the factor/trend
	• Continuing ocean acidification and rising ocean temperatures are threatening marine species natural habitats, and negatively affecting marine ecosystem services. Between 2009 and 2018, the world lost about 14% of coral reefs. • The global coverage of marine protected areas stood at 8% of global coastal waters and oceans in 2021. • In the coming decade, a crucial challenge will be water security. In addition to the effects of global warming, water availability is directly affected by increasing demand for water from industry, agriculture, urbanisation and tourism. This escalates global demand for renewable energy, which is strongly water-dependent, saline intrusions and the pollution of surface- and groundwater. There are multiple risks associated with water scarcity: loss of livelihood due to increasing water variability, modification of river streams and morphology, transmission of pollution to the entire water system.	
Technological	• Digitalisation, Artificial Intelligence (AI), European Open Science Cloud and EU data spaces including, digital twins • Research and technology infrastructures • Sea defence solutions against marine litter at source (on rivers) or at sea. • Blue carbon • Carbon Farming • Biotechnology • Improved modelling of environmental processes • Improved environmental monitoring sensors and systems	• Contributing to digital marketing and EU data spaces • Pollution remediation and prevention, ecosystem restoration • Technological and nature-based solutions supporting planet's health management and restoration • Modelling and forecasting capacity, considering the stressors' continuum and predicting their impact over the relevant hydrosphere nexuses (with climate, food and water security, human and animal health), integrated over space and time.

Type of factor/trend	Description	Short summary of the expected impact of the factor/trend
Geopolitical/ governance	• UNCLOS High Seas Treaty (2023): Kunming-Montreal Global Biodiversity Framework, Montreal December 2022: countries pledged to protect at least 30% of terrestrial and marine areas, while also recognizing Indigenous and traditional territories. • Paris Agreement (2016): More countries are making plans to boost their resilience and capacity to adapt to climate change, raising the number of parties that ratified or acceded to the Paris Agreement, from the initial 114 in 2016 to 186 in 2019, and to 194 states and the EU (as of February 2023), representing over 98% of global greenhouse gas emissions, including China and the United States, the countries with the 1st and 2nd largest CO2 emissions among UNFCCC members. • EC new agenda on international ocean governance (2022) (European Commission, 2022a)	• Improved governance • Targeted policy - achieving SDGs objectives, e.g.: for the Climate action, Life below water, clean water and sanitation, zero hunger. • Halt and reverse the loss of marine biodiversity, fight climate change and marine pollution for a healthy ocean, protect the seabed from harmful practices, ensure a sustainable blue economy and build up ocean knowledge, ensure security and safety at sea and a compliance with international rules and standards • Protecting biodiversity in waters beyond national jurisdiction • integrated planning of maritime space
Ethical	• UNESCO UN decade of ocean science for Sustainable development (2022): 45 programmes, 200 projects self-contributing; 45 national decade committees, seeds of interdisciplinary ocean management structures; includes ethics. • The High-Level Panel for a Sustainable Ocean Economy	• Ocean empathy; empowered women; ocean professionals • Sustainable hydrosphere governance conscience • Sustained hydrosphere management and planning capacity
Economic	• Losses in the order of €3-20 trillion per year in ecosystem services and of €5.5-10.5 trillion per year due to land degradation. • Almost half a billion people depend at least partially on small-scale fisheries, which account for 90 per cent of employment in fisheries worldwide.	• Poor water quality and sanitation, food scarcity, poverty, hunger, unemployment, warfare.

Figure 16. Identified main factors or trends influencing the mission area

Source: Authors based on cited references

The evidence suggests that there will be no alleviation of global warming, demographic pressure, use of resources and man-made pollution; and that measures to reduce the impact of human activity on planetary natural ecosystems will continue to be a priority to avoid mass extinction(s) (ESPAS, 2019). Progress towards this goal can be measured, notably, based on the trends in SDGs. The latest SDG Report (United Nations, 2022) indicates that:

- Continuing ocean acidification and rising ocean temperatures are threatening marine species and negatively affecting marine ecosystem services. Between 2009 and 2018, the world lost about 14% of coral reefs.

- In 2021, more than 17 million metric tons of plastic entered the world's ocean, making up 85% of marine litter. The volume of plastic pollution entering the ocean each year is expected to double or triple by 2040.

- The global coverage of marine protected areas stood at only 8% of global coastal waters and oceans in 2021.

- More than a third (35.4%) of global fish stocks were overfished in 2019, up from 34.2 per cent in 2017 and 10% in 1974. However, the rate of decline has recently slowed.

- Almost half a billion people depend at least partially on small-scale fisheries, which account for 90% of employment in fisheries worldwide.

According to the Eurostat barometer (2022)[25], the EU has made good progress towards the SDG 'Life below water' (SDG14): while the trends for the various indicators of the status of this goal show a varied pace of progress, the overall progress is generally significantly positive. On the other hand, this goal needs to be considered also through its relationship with other SDGs and related indicators, considering that the biggest sources of pollution to the oceans are land-based (hence a clear linkage with the mission area on soil health). The status in clean water and sanitation (SDG6) and zero hunger (SDG2) is less reassuring, showing that the concentration of nitrates and phosphates in rivers and ground water systems is moving away from the target value. While only moderate progress is achieved for the climate action (SDG 13).

In 2021, the EC second annual Strategic Foresight Report 'The EU's capacity and freedom to act' (European Commission, 2021c) presents climate change and other environmental challenges as a main stressor on the EU's capacity and freedom to act in the coming decades, highlighting a particularly alarming situation regarding biodiversity loss and change in the nitrogen cycle, mainly induced by mass agricultural and breeding practices, with a scale of change far superior than the modification of the carbon cycle, affecting freshwater, coastal areas and human health. Economic consequences estimate losses for €3.5-18.5 trillion per year in ecosystem services from 1997 to 2011 and an estimated loss of € 5.5-10.5 trillion per year due to land degradation. Ultimately, public health, food crops and animal health will be endangered.

Finally, the EU Green Deal Barometer (IEEP, 2022) indicates that the commitment of the MS to the EU Green deal implementation is at risk, given the unforeseen challenges faced by the EU, including the recent pandemic, the war in Ukraine and the related energy crisis. The experts consistently identified the lack of commitment by Member States as the biggest obstacle to the implementation of the Green Deal agenda. Similar concerns of derailing policy

[25] https://ec.europa.eu/eurostat/cache/website/sdg/sdg_key/sdg_key_2022/index.html?lang=en

implementation in the context of the emerging crisis have also been expressed in the 2022 SRIP report (EC Commission, 2022g). Also interviewees flagged that due to the pandemic and war in Ukraine the political attention to biodiversity in general is waning, while commitment to ocean matters hold strong.

Given the evidence presented above, it is evident that the recent developments reinforce the relevance of the mission area for the challenges that Europe is facing and, in fact, for saving the planet from the negative impacts caused by human activity.

4.3. Protecting the hydrosphere: insights from international examples

The EU has been a pioneer in adopting mission-oriented policies through initiatives like Horizon Europe and the European Green Deal. While similar approaches are being adopted by countries worldwide to stimulate innovation, address societal needs, and promote sustainable development, we could not locate a specific mission targeting the area of healthy oceans, seas, coastal and inland waters. However, several countries around the world have implemented initiatives and policies to address the health and conservation of their marine and freshwater ecosystems, as demonstrated in the table below.

Country (or multi-country region)	Mission policy title (& year initiated)	Definition of mission area
Canada	Ocean Policy Plan (OPP), 2016	Canada policies and regulations for protecting its water resources, include a Water Act and a Fisheries Act. These policies aim to ensure the conservation and sustainable management of freshwater ecosystems and protect aquatic species. In 2016, the Government of Canada launched the $1.5 billion Oceans Protection Plan (OPP), which represents the largest investment ever made to protect coasts and waterways, from the potential impacts of marine shipping, and to ensure the health of oceans. The OPP involves five federal departments, with Transport Canada (TC) as the designated lead department. Partnership and collaboration are the foundation of the Government of Canada's actions to protect their oceans. The OPP places a strong emphasis on collaboration with the provinces, indigenous organisations, marine industries, environmental organisations, coastal communities, and the public.
Australia	National Water Quality Management Strategy (NWQMS), 1992	The NWQMS was introduced in 1992 and incorporated into the Council of Australian Governments (COAG) Water Reform Framework in 1994. It contributed to the development of a national policy to sustainably manage Australia's water resources by protecting and enhancing their quality while maintaining economic and social development. The NWQMS follows the guiding principles set out in the National Strategy for Ecologically Sustainable Development, which was also endorsed by COAG in 1992. An independent review of the NWQMS conducted in 2011 highlighted that the policy outline had not been updated in over 20 years. While knowledge and expertise on managing water quality has grown, the key NWQMS documents still lack reference to global stressors such as global warming, ocean

Country (or multi-country region)	Mission policy title (& year initiated)	Definition of mission area
		acidification and climate change, disruption of the carbon and nitrogen cycles. In 2018, the Australian government issued the design and requirements for a new guideline to the National Water Quality Management Strategy, which could be included under the NWQMS, covering a range of subjects, including: • protecting fresh and marine water ecosystems • defining and managing safe drinking water • defining water quality that is safe for recreational uses • managing health and environment risks of recycled water use • defining water that is safe for irrigation use, for livestock and for aquatic organisms that are used for human consumption) • protecting groundwater. Purpose: The purpose of the NWQMS is to protect the nation's water resources by maintaining and improving water quality, while supporting dependent aquatic and terrestrial ecosystems, agricultural and urban communities, and industry. Channels for delivery of the NWQMS are: • Policy that enables effective water quality management for the delivery of fit for purpose water that supports community values, such as aquatic ecosystems, cultural and spiritual values, drinking water, industrial water, primary industries, recreation and aesthetics. • Process (framework) for the development and implementation of management plans. These plans focus on the reduction of pollution released into coastal pollution hotspots and other aquatic ecosystems. • Guidelines that are developed using best available scientific evidence, providing benchmarks and targets for managing water quality across a range of risk profiles and uses. The NWQMS is non-mandatory but utilised by all state and territory governments in establishing their own guidelines, regulations, policies, processes and/or standards for managing the quality and supply of water that is fit for purpose. The Australian Government also utilises the NWQMS for various purposes such as meeting international obligations. Oversight of the NWQMS is managed through a series of committees and

Country (or multi-country region)	Mission policy title (& year initiated)	Definition of mission area
		working groups, responsible for different levels of governance of the strategy, its projects and goals.
India	National Action Plan on Climate Change, 2008 National Water Mission, 2011	The Government of India has established National Water Mission in 2011 as one of the eight National Missions under the National Action Plan on Climate Change of 2008. The main objective of NWM is "conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within States through integrated water resources development and management". NWM has identified five goals as under: • Comprehensive water data base in public domain and assessment of the impact of climate change on water resource, • Promotion of citizen and state actions for water conservation, augmentation and preservation, • Focused attention to vulnerable areas including over-exploited areas, • Increasing water use efficiency by 20%, and • Promotion of basin level integrated water resources management. Various strategies for achieving the goals have been identified which led to integrated planning for sustainable development with active participation of the stakeholders.
Brazil (Porto, 2000)	National Water Act (1997)	The National Water Act of 1997 (Law 9.433) defines the objectives, principles, and instruments of the National Water Resources Policy and the National Water Resources Management System. The law establishes the institutional arrangement under which the country's water policies are to be implemented. The Brazilian Water Resources Policy was proposed to achieve (1) sustainability-- to ensure that the present and future generations have an adequate availability of water with suitable quality; (2) integrated management-- to ensure the integration among uses in order to guarantee continuing development; and (3) safety-- to prevent and protect against critical events, due either to natural causes or inappropriate uses. To achieve such objectives, water management must be implemented according to the following principles: 1. water is a public good; 2. water is a finite resource that has economic value;

Country (or multi-country region)	Mission policy title (& year initiated)	Definition of mission area
		3. the use of water required to meet people's basic needs shall have priority, especially in critical periods; 4. water management shall comprise and induce multiple uses; 5. the river basin is the appropriate unit for water management; 6. water management shall be decentralised, with the participation of government, stakeholders and society. These same principles are viewed today as the embodiment of modern water management. Together they encompass such themes as protection of the environment, economic development, and improvement of social conditions, all of which are intended to achieve sustainability. The general guidelines for implementing the water resources policy emphasize the need for integrated management, flexibility to accommodate regional differences, coordination among the different sectors, land use planning (relevant to water management), and integration between inland and coastal water management. The specific tools outlined in the Act to implement the policy include (1) water resources plans; (2) classification of water bodies for different use, resulting water quality standards tailored to the target use of each water body, (3) a permit system for withdrawal or use of water; (4) water pricing; and (5) a water resources information system.
Indonesia[26]	National Plan of Action on Marine Plastic Debris 2017–2025	The plan aims to prevent both land-based and ocean-based leakage of plastics, with a 70% reduction of marine plastic relative to business as usual by 2025. Land-based efforts include the production of biodegradable plastics, the reuse of plastic waste (e.g. in plastic asphalt roads) and charges for plastic bags; while ocean-based efforts include reception facilities at ports, the collection of waste from marine and coastal areas, and plastic waste management in tourism. The plan involves 16 ministries and institutions across 59 activities and a framework for the involvement of the private sector in addressing waste was approved. The National Plastic Action Partnership was launched in 2019 by the Ministry for Maritime Affairs and Investments as a platform for public-private collaboration and includes over 150 member organisations and businesses. Measures to address marine plastic waste include taxes and bans on single-use plastic, clean-up efforts, awareness rising. It is foreseen to deploy R&I for biodegradable plastics,

[26] https://www.oecd.org/ocean/topics/ocean-pollution/marine-plastics-pollution-Indonesia.pdf

Country (or multi-country region)	Mission policy title (& year initiated)	Definition of mission area
		circular economy solutions, waste to energy, modelling plastics leakage and flow.
USA	Clean Water Act, 1972 Ocean Dumping Act, 1972	The Clean Water Act (CWA)[27] establishes the basic structure for regulating discharges of pollutants into US waters and regulating quality standards for surface waters. The CWA was enacted in 1948 as the Federal Water Pollution Control Act and was significantly reorganised and expanded in 1972 as the CWA which made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. The Environmental Protection Agency (EPA) implements pollution control programmes such as setting wastewater standards for industry and has also developed national water quality criteria recommendations for pollutants in surface waters. implements and enforces these regulations to ensure the protection of the country's water resources. The Marine Protection, Research, and Sanctuaries Act of 1972 regulate intentional ocean disposal of materials, and authorises related research. In 1992, Congress amended the act to permit states to adopt ocean dumping standards more stringent than federal standards and to require that permits conform with long-term management plans for designated dumpsites, to ensure that permitted activities are consistent with expected uses of the site. The National Oceanic and Atmospheric Administration (NOAA) has various programmes and initiatives focused on the conservation and sustainable management of oceans and coastal areas, including efforts to protect marine species, mitigate pollution, and promote ecosystem resilience.
Nordic countries	Nordic Innovation Sea Meets Land mission (2020)[28]	The Nordic Innovation Mobility Mission: “Sea Meets Land” (2020) is the effort to support Nordic initiatives seeking to develop solutions to decarbonize Nordic ports, transport of people and goods – on and between sea and land. NOK 8 million. 12-month funding period dedicated to building the project, strengthening the consortium, sharpening or refining the Nordic strongholds that the project aims to combine/develop to achieve the ambitions of the Mobility Mission. The Ministers for Nordic Co-operation have an overall responsibility for following up on the implementation of the vision and the strategic priorities.

Figure 17. Overview of relevant benchmark mission-type policies

Source: authors based on referenced material

[27] https://www.epa.gov/laws-regulations/summary-clean-water-act

[28] https://www.nordicinnovation.org/seameetsland

Overall, the review of approaches to creating a strategic framework for addressing ocean and waters challenges in other countries suggests a more targeted approach which seeks to improve water management practices, reduce pollutants (e.g. plastics) or protect marine environments. A fully-fledged MOIP approach does not appear to have been adopted in the cases reviewed, even if there is a shift towards such an approach in several of the cases over time. The pioneering nature of the EU mission in this area is evident.

4.4. Key lessons from the review of the mission area

The mission area of healthy oceans, seas, coastal and inland waters is a multidimensional space influenced by very varied external factors, such as environmental conditions, ecological stressors, societal approaches, political governance, and management. With respect to the challenges faced at the EU as well as the global scale, the trends of relevant indicators in the mission area healthy oceans, seas, coastal and inland waters are still as alarming and, while some negative trends may have attenuated in intensity, some have even worsened. Considering that this mission area addresses challenges that threaten life as we know it on this planet, it is evident that the mission area remains fully relevant for Europe and that a system-approach is required to address the complexity and multitude of the factors influencing this area, such as interdependent environmental conditions, ecological stressors, societal approaches, political governance and management. However, a risk is that the current 'transversal crisis derails the political commitment to the highly ambitious EU policy objectives and jeopardise the necessary support to R&I actions and the establishment of the required collaborative frameworks.

R&I is at the core of the provision of knowledge and solutions (both technology- and nature-based) to accompany the achievement of goals set in the EU strategies (Green Deal and the Digital Strategy - Digital Agenda); as well as contribute to global initiatives such as the UN Agenda 2030 for Sustainable Development and the UN Ocean Decade of Ocean Science for Sustainable Development (2021-2030). In particular: investigating the interdependencies among the elements of the water-climate nexus, and how this impacts life on Earth is at the core of a fuller understanding of the dynamics of this area and identification of opportunities for intervention, mitigation, and adaptation strategies. The novel dimension of ocean ethics should be better highlighted to produce a cultural shift and behavioural change at the individual scale, regarding the impact of human activity on the hydrosphere. The use of digital technologies for representing and managing the water continuum are also a rather novel element for R&I action, which can support a modern ocean governance and management system.

It is evident that EU and national policies need to uptake the state of the art in this area. The review suggests that while several countries around the world have implemented initiatives and policies to address the health and conservation of their marine and freshwater ecosystems, **a policy mission-area definition as all-encompassing as in the EU approach is unique**. This provides an opportunity for EU global leadership on this critical 'grand challenge' for all on Earth.

5. Mission area: climate-neutral and smart cities

5.1. The scope and definition of the mission area

The selection of the mission area 'climate-neutral and smart cities' responds to the recommendation of the Lamy Report to define missions that "are open to all actors in the research and innovation cycle, in particular new actors of innovation and change such as cities and regions, which could act as 'innovation laboratories of change' in piloting new ideas and concepts".[29] Even closer to the mission area, Mazzucato (2018) proposed that '100 climate-neutral cities by 2030' would meet all criteria of a promising mission. The idea was also taken up by the High-Level Panel of the European Decarbonisation Pathways Initiative, which proposed a mission to be formulated in the area of "climate-neutral, 'circular' and liveable cities" alongside a mission on soil as carbon sinks and a mission for the full integration and decarbonisation of the energy system (EC 2018b, p. 165). In its interim recommendations, the panel considered further mission areas for decarbonisation: a mission on smart storage and transmission, a mission on renewable and sustainable plastics, and a mission on zero-carbon and sustainable construction materials (EC, 2018c, p. 251). While carbon storage has been included in the mission area 'soil health and food' (see Section 6), 'climate-neutral and smart cities' is the only mission area to address climate mitigation.

5.2. Review of the mission area

The terms 'climate-neutral' and 'smart' are neither coherently defined in European policy-making, nor in the scientific literature (Correia et al. (2022), Echebarria et al. (2021), Huovila et al. (2022)). While this creates challenges for both the implementation and monitoring of missions[30], climate neutrality and smartness are well established categories in urban and European governance, which facilitates interactions across governmental units. In particular, the mission area is tightly linked to the aim of achieving a climate-neutral economy in Europe by 2050 (EC, 2018a) and EC's growth model of a green and digital 'twin transition' (EC, 2022)[31]. **The mission area connects to previous cross-national city initiatives for climate action** (e.g. Carbon Neutral Cities Alliance, C40 Cities, Climate Alliance, Energy Cities, Global Covenant of Mayors for Climate and Energy) and smart cities (e.g. 100 intelligent cities challenge, smart cities marketplace, United for Smart Sustainable Cities).

The broad thematic scope of the mission area calls for holistic and cross-sectoral solutions to urban challenges. According to the latest IPCC climate mitigation report, cities "can only achieve net-zero GHG emissions through deep decarbonisation and systemic transformation (*very high confidence*)" (IPCC, 2022, p. 864). Furthermore, the scope of the mission area makes it well placed to deliver significant contributions to SDGs 11 (sustainable cities and communities) and 13 (climate action).[32] When the mission area was defined, SDG 13 was among the goals where the EU had been making the least progress; while for SDG 11, the EU had made moderate progress overall but there were negative trends in the climate-relevant domains of per capita settlement areas and share of public transport (EU, 2019).

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[29] EC (2017, p. 15 emphasis on 'are open to all actors' omitted).

[30] The challenges in the communication of the mission, in particular the transparent communication of scope of emissions and in engagements with citizens, are discussed in the Mission Assessment Report.

[31] Furthermore, the mission area corresponds to a range of EU policy objectives (Di Girolamo et al., 2022, p. 329).

[32] The mission board proposed that the mission may also deliver major contributions to SDGs 3, 7, 8, 9, 12, 14, 15, 17 and moderate contributions to SDGs 5 and 10 (Gronkiewicz-Waltz et al., 2020, pp. 8–9).

The mission area is thus linked to some of the key sustainable development issues Europe was facing at the time of its selection.

Due to its broad scope, the mission area addresses many significant societal challenges in domains such as mobility and transport, urban greening, energy provisioning, and buildings (Dinges et al., 2021). Tackling GHG emissions of cities has a high potential to deliver rapid and large-scale contributions to decarbonisation while creating co-benefits with respect to air quality, heat stress, as well as mental and physical health[33]. However, the mission area does not address the "urgent need to integrate urban mitigation and adaptation for cities" identified in the scientific community (IPCC, 2022, p. 864). Furthermore, with respect to climate mitigation, the mission area provides no indication of the relative priority to be given to different strategies of GHG emissions reduction, compensation, and neutralisation, a matter that remained unresolved in the implementation of the mission (Shabb et al., 2022). At the same time, by including the notion of 'smart', the mission area is the only one that gives some direction in terms of the means to be implemented to address a societal challenge. In contrast to this technological directionality, the mission board converged on the idea that the mission should be "technology-neutral" and start with a "human-centric framing" (EC, 2019). The perspective reflects a debate in the scientific community, on whether smart city frameworks tend to neglect the proactive roles of citizens and are based on a model of programmable cities that can be monitored and controlled in real-time[34]. Such a model is diametrically opposed to an emphasis on citizen engagement and participation in MOIP. Instead of narrowing the scope, the mission board proposed to adopt a focused approach on climate neutrality and put stronger emphasis on the involvement of and co-benefits for citizens.[35]

In the interviews and stakeholder workshop, some participants reiterated that the mission area definition is not ideal for engaging citizens. While in some languages climate-neutrality has a different connotation, **the main issue appears to be the rather technical framing of the mission area, which may limit its inspirational value**. Neither 'climate-neutral' nor 'smart' convey the benefits for citizens, let alone provide a sense of how the cities of tomorrow are envisaged. The stakeholders reported using different notions in communicating to citizens, emphasising instead that the mission is about developing 'green' and 'healthy' cities.

5.2.1. The role of R&I in addressing the challenges

MOIP addresses societal challenges that require the development of novel and potentially radically different solutions (EC/Mazzucato, 2018). The continued relevance of the mission area is conditional upon its ability to address persistent challenges in Europe through R&I. This said, the anchoring in Horizon Europe and the concomitant focus on R&I is a disputed issue among interviewees and survey respondents. **There is a strong consensus among interviewees that R&I will not be sufficient and that the main challenges for cities in transitioning to climate neutrality lie elsewhere**. In line with this assessment, several survey respondents emphasised that greater attention needs to be paid to implementation, transformation, and financing. The apparent gap between the capacities of policy instruments at DG RTD's disposal, on the one hand, and the needs of cities on the other side is a common source of frustration among stakeholders consulted. The key issue, however, is not to move from innovation to implementation but, about finding: *"a balance between calls addressing research needs and implementation needs, leaving enough space for innovation, in particular social innovation, governance innovation and process innovation. Finding synergies between*

[33] Floater et al. (2016), IPCC (2022), Material Economics (2020)

[34] For example, see Cardullo & Kitchin (2019), Corsini et al. (2019), and Engelbert et al. (2019)

[35] The Mission Assessment Report discusses the scope of the cities mission.

the challenges on the ground and the potential of academia is crucial to allow all stakeholders to find their role in the mission implementation." (survey respondent)

The statement highlights **the need to consider non-technological innovations and the important role of R&I in providing stakeholder orientation, not before but during implementation**. Similarly, the mission board acknowledged the significance of digital technological and systems but stressed that urban transitions to climate neutrality also necessitate innovations along "social, creative, organisational, and financial" dimensions (Gronkiewicz-Waltz et al., 2020, p. 19). Following an understanding that the "main obstacle to climate transition is not a lack of climate-friendly and smart technologies, but the capacity to implement them", the mission board proposed that a mission in the area of climate-neutral and smart cities should address "system innovation in the whole value chain of city investment" (Gronkiewicz-Waltz et al., 2020, p. 5), locating key innovation challenges in the domains of city administration and governance, finance and capital, as well as business models and market structures. This perspective has wide support from the study participants in interviews, survey, and the workshop, who endorsed a shift towards system innovation, confirmed the persistent innovation needs in these domains, and suggested that learning and experimentation remain crucial.

Furthermore, in going beyond implementation and addressing the scaling of local solutions, the decision to launch a mission on climate-neutral and smart cities tackles a key challenge at the forefront of scientific debates.[36] Figure 18 compiles some key contributions that R&I is expected to deliver in response to urban challenges, drawing on four reports prepared by expert groups commissioned by the EC. In sum, **the review suggests that R&I will likely remain of high relevance for climate-neutral and smart cities**.

Urban challenges	Expected contributions of R&I (illustrative)
Mobility and transport	Shared, autonomous, multi-modal mobility and mobility-as-a-service for fewer cars; electrified vehicles reducing demand for fossil fuels; mobility system optimisation for reductions of passenger-kilometres; 3D printing reduces need for freight transport; remote maintenance and smart products reduce; faster public transport (e.g. hyperloop) connect cities and curb urban sprawl; data analytics and technologies improve traffic management and avoid congestions
Energy systems	Internet of Things solutions for remote control of street lighting; better understanding of the role of cities in producing electricity and heat locally
Built environment	Durable, mixed-use buildings for less material demand; modular designs for reuse of building components; new financing schemes to overcome high upfront costs of building retrofitting
Governance and planning	Estimating costs of making a city climate-neutral in a smart way; methodologies to calculate monetary co-benefits of low-carbon solutions; systematic screening of windows of opportunity for applying smart, climate-neutral solutions; understanding stability and vulnerability of climate-neutral and smart infrastructures to mitigate risks; guidelines to help local administrations of how to induce behavioural change; understanding motivations for companies to make more sustainable choices; knowledge of

[36] See Bundgaard & Borrás (2021) and van der Heijden (2022)

Urban challenges	Expected contributions of R&I (illustrative)
	how to balance public and private interests of technical and ICT operators; knowledge how governance can enable decarbonisation in cities
Everyday life	Knowledge of evolving needs; understanding conditions for better quality of life; nudges for sustainable behaviour change; understanding requirements to protect security of individual data amidst development of advanced digital technologies; understanding the social acceptance of climate-neutral cities; social innovations for stronger citizen engagement
Urban system	Design of integrated and zero-carbon systems to reduce energy demand and improve energy efficiency; better understanding of the co-benefits of climate action in cities; knowledge on pathways to climate-neutrality depending on local conditions of cities

Figure 18. Expected contribution of R&I to addressing the mission area challenges.

Source: Authors based on Dinges et al. (2021), European Commission (2018b), Peiffer-Smadja et al. (2022), Ricci et al. (2017)

5.2.2. Developments influencing the mission area

Five years after its formulation, the mission area remains highly relevant. The foresight study prepared in support of the mission selection process identified a series of key trends affecting pathways to climate-neutral and smart cities, such as urbanisation, an ageing population, digitalisation, climate change, and migration inflows (Dinges et al., 2021). Most of these trends have continued and even intensified as summarised in Figure 19. The COVID-19 pandemic and the war in Ukraine have had severe repercussions for European cities, the longer-term implications of which are difficult to foresee. In general, cities have become more vulnerable to transnational and global trends, while increasingly lacking the financial capacities to push forward a transformation process.

The situation for cities has become more difficult and they are facing enormous challenges with respect to climate mitigation. To achieve climate-neutrality by 2050, the EU stepped up its goal of reducing GHG emissions to at least 55% (instead of 40%) below 1990 levels by 2030.[37] Projections of future GHG emission trends suggest that existing and additional measures the EU and its Member States plan to launch in the coming years will not be sufficient to reach this target. To meet short- and long-term targets, the pace at which improvements in energy efficiency and the share of renewable energy have been achieved to date needs to be accelerated significantly throughout the coming decades. Whereas significant progress has been made in reducing GHG emissions in energy supply and industrial processes, much more effort is required in transport, agriculture, and the building sectors (EEA, 2022). In the past five years, Europe moved away from the trajectories needed to comply with its climate targets in critical domains linked to urban development, in particular with regard to opposing trends in the share of public passenger transport, average CO_2 emissions from new passenger cars, and spread of settlement areas (Eurostat, 2022).

[37] European Parliament & Council of the European Union (2021).

Climate mitigation is far from the only challenge cities are facing today. Many of the trends listed in Figure 19 put high environmental and social pressures on cities, which tend to have spatially and socially unequal effects and are not explicitly addressed by the mission area.

Type of factor/trend	Short summary of the expected impact of the factor/trend
Environmental • Climate change exacerbates the impacts of natural disasters, energy poverty, water scarcity, and extreme weather conditions • Growing urban greenspaces • Declining share of public passenger transport • Increasing CO2 emissions from new passenger cars • Reduction of CO2 emissions in energy supply and industrial processes	In light of the slow progress made in climate mitigation, implementing a mission in the area of climate-neutrality raises the political ambition to meet a major and still unresolved societal challenge. As global warming continues, climate adaptation may become a more important concern for citizens and policymakers.
Social • Urbanisation • Ageing population • Increasing urban sprawl • Growing migration inflows	Urbanisation and the growing population make cities increasingly critical sites of climate action.
Geopolitical • Declining dependency from Russian energy imports • Disruptions of global supply chains, especially in automobile and electronics sectors • EU financial and trade sanctions against Russia • Industrial policy initiatives like the U.S. Inflation Reduction Act may reduce the competitiveness of European industries	Shortages of energy and electronics could have strong negative effects on decarbonisation and digitalisation efforts. Cities increasingly rely on national governments to secure supply chains, build energy infrastructures, and support industries for green products and services.
Policy	Repeated global and supranational crises could threaten EU's and national governments political support for climate action and digitalisation at the city

Type of factor/trend	Short summary of the expected impact of the factor/trend
• Cities are moving towards integrated planning and new forms of governance • Growing environmental awareness and rising citizen participation • Climate-neutrality and digitalisation have been gaining priority in EU and its Member States, but the COVID-19 pandemic, war in Ukraine, and increasing geopolitical tensions have recently directed attention away from these goals.	level. If deep crises can be averted, the political environment is favourable for missions on climate-neutral and smart cities.
Technological • Accelerating digitalisation • Growth of digital-enabled services	While transitions to 'smart' cities are under way, the effects of digitalisation on carbon-neutrality are mixed.
Economic • Stagnating tax revenues of city governments • Decreasing affordable housing • High inflation rates, especially for energy • Shortage of skilled workers • Rising economic inequality and urban segregation	Intensifying financial pressures at the local level, especially in city governments and among most vulnerable social groups, call for increased support at the regional, national, and EU level. The shortage of skilled workers may significantly slow down decarbonisation.

Figure 19. Identified factors or possible trends influencing the mission area

Source: Authors based on Dinges et al. (2021), European Committee of the Regions (2022), Vandecasteele et al. (2019)

5.3. Boosting climate neutrality of cities: insights from international examples

Figure 20 and Figure 21 provide an overview of existing policies in EU and non-EU countries related to climate neutrality, smartness, and cities as well as their respective mission areas.[38] The overview reveals that climate change, and the low-carbon transition are commonly addressed areas in policies adopting a mission-oriented approach. Outside the EU, however, there are only a few cases of MOIP addressing issues covered by the mission area of climate-neutral and smart cities (see Figure 21).

The EC has become a global frontrunner in connecting climate agendas with the city level through mission-oriented innovation policy. In addition to the cities mission, the EC spearheads the 'urban transitions' mission, a mission operating under the umbrella of the 'mission innovation' initiative. The mission builds on the cities mission but has a global reach and includes the government of India among its core members. Compared to the cities mission, the urban transitions mission is very similar in ambition as far as the emphasis on holistic solutions and involvement of citizens is concerned but focuses on 'pathways' as opposed to concrete outcomes such as climate neutrality.[39] Furthermore, and despite the strong representation of the EC and EU Member States in the mission, the mission area is defined very differently in terms of 'net-zero, resilient, and people-centred cities'.[40] The notion of resilience reflects the mission's ambition to integrate climate mitigation and adaptation strategies.

Moreover, digital solutions play a subordinate role in the urban transitions mission. This more technology-neutral or people-centred approach is also reflected in the definition of mission areas in Austria and Sweden. Whereas in Austria the mission area is defined solely as "climate-neutral city", the aforementioned 'viable cities' initiative from Sweden added the emphasis on providing "a good life for all within planetary boundaries", thus stressing also social inclusiveness and ecological compatibility. Following again a different approach to urban transitions, India launched a mission specifically dedicated to smart cities. The mission addresses a broad area to foster inclusive and sustainable development in cities but defines a set of ten core infrastructure elements to make the scope of the mission more tangible. Elements include robust IT connectivity, digitalisation, and e-Governance but also themes closer to climate neutrality such as 'sustainable development' and 'efficient urban mobility and public transport'.

The remaining mission-related policies listed in Figure 20 and Figure 21 address elements of climate neutrality and smartness without a dedicated focus on cities. Instead, several initiatives follow an approach of providing an 'umbrella framework' (Larrue, 2022) that brings together multiple missions under a common strategic agenda.

[38] The lists are based on compilations of MOIP by Larrue (2021, 2022). Additional entries were identified through cross-references in mission policy documents. For the purposes of this section, the analysis does not consider challenge-led policies based on prizes (e.g. Ireland) and higher-level strategies (e.g. Japan's Society 5.0, Canada's Pan-Canadian Framework on Clean Growth and Climate Change).

[39] In this sense, the urban transitions mission is more similar to the European Partnership 'Driving Urban Transitions towards a Sustainable and Liveable Urban Future' than the cities mission.

[40] Mission Innovation (2022, p. 1)

Country	Mission policy title (& year initiated)	Definition of relevant mission area(s)
Austria	Thematic focus areas (2022)[41]	Climate-neutral cities; energy transition; mobility transition; circular economy
Denmark	Green missions (2021)[42]	Capture and storage or use of CO_2; green fuels for transport and industry; climate- and environment-friendly agriculture and food production; circular economy with focus on plastics and textiles
Finland	Flagship programme (2017)[43]	Climate neutrality in Finland, EU and global societies, mitigate air pollution to sustain a healthy atmosphere (atmosphere and climate competence centre), future biorefineries, clean air and water, lignocellulosics beyond plastics, and electronics, optics and energy applications (competence centre for the materials bioeconomy); wireless connectivity, devices and circuit technology, distributed computing, and sustainable, human-centric services and applications (6G-enabled wireless smart society & ecosystem)
France	France 2030 (2021)[44]	Small, innovative nuclear reactors in France with better waste management; green hydrogen and cutting-edge renewable energy technologies; decarbonisation of industry and input production; zero-emission vehicles in France and sustainable, sovereign, and resilient mobility; low-carbon aircraft; healthy, sustainable and traceable food
Germany	High-Tech Strategy 2025[45]	Digital economy and society; sustainable economy and energy; intelligent mobility
Lithuania	Mission-based science and innovation programmes (2023)[46]	Smart and climate-neutral Lithuania; a secure and inclusive e-society
Netherlands	Mission-driven top sector policy (2019)[47]	Reduction of national greenhouse gas emissions; carbon-free electricity system; carbon-free built environment; carbon-neutral industry with reuse of raw materials and products; zero-emission mobility

[41] https://www.bmk.gv.at/themen/innovation/schwerpunkte.html, on the cities mission: https://nachhaltigwirtschaften.at/resources/nw_pdf/eia/eia_224_en.pdf

[42] https://innovationsfonden.dk/en/p/grand-solutions/grand-solutions-realization-four-green

[43] https://www.esitteemme.fi/flagships/WebView/

[44] https://investinfrance.fr/wp-content/uploads/2017/08/FR-2030_Dossier_Presse_A4-v07-BAT-EN.pdf

[45] https://ec.europa.eu/futurium/en/system/files/ged/hts_broschuere_engl_bf_1.pdf

[46] https://eimin.lrv.lt/en/news/almost-eur78-million-for-mission-based-science-and-innovation-programmes

[47] https://open.overheid.nl/documenten/ronl-c836d802-d3c2-45d6-aad4-0c7b011dae61/pdf

Country	Mission policy title (& year initiated)	Definition of relevant mission area(s)
		of people and goods; a sustainable and completely circular economy; circular agriculture; net carbon-neutral agriculture and nature system; production and consumption healthy, safe and sustainable food
Spain	Science and innovation missions (2021)[48]	Strengthen technological capabilities for secure and sustainable energy autonomy (fusion, hydrogen and renewables); promote the substitution, recovery and valorisation of mineral resources and strategic materials for the ecological transition
Sweden	Healthy sustainable food (2019)[49]	Ensure that every student in Sweden eats healthy, sustainable and tasty school food

Figure 20. Overview of mission policies and their respective mission areas in EU countries

Source: authors based on referenced material

In the United States, which like the EC have set the goal to become climate-neutral by 2050, the Department of Energy initiated multiple 'energy earthshots' in support of this goal. Each 'shot' addresses a different area linked to climate neutrality focusing on technologies for carbon removal, reduction, or avoidance.[50] The initiative puts a strong emphasis on R&D and the acceleration of technological innovation to ignite breakthroughs in the energy system and carbon cycle. Moreover, all shots aim to radically drive down the costs of technologies, defining cost-per-unit targets to be achieved within a decade in the cases of the hydrogen shot and the carbon negative shot or by 2035 in the remaining shots.

A similar approach has been adopted in the global 'mission innovation' initiative, which attributes high importance to achieving improvements in cost-effectiveness. Alongside the urban transitions mission, the initiative encompasses multiple missions targeting different areas of climate neutrality, notably carbon dioxide removal, clean hydrogen, renewable energy systems, and net-zero industries. Innovations in energy and carbon technologies are also at the core of MOIP in Australia, Canada, Norway, and the United Kingdom. Hydrogen fuel represents a focal area across almost all initiatives outside the EU. Compared to this emphasis on energy technologies, it is noteworthy that several EU Member States, in particular Austria, Denmark, the Netherlands, Spain, and Sweden, formulated mission areas directly targeting the bioeconomy or circular economy.

[48] https://www.cdti.es/index.asp?MP=100&MS=902&MN=2

[49] https://www.vinnova.se/contentassets/1c94a5c2f72c41cb9e651827f29edc14/designing-missions.pdf?cb=20220311094952

[50] https://www.energy.gov/policy/energy-earthshots-initiative

Country (or multi-country region)	Mission policy title (& year initiated)	Definition of relevant mission area(s)
Australia	Hydrogen industry mission (2021)[51]	Hydrogen research, development and demonstration
Canada	Materials for clean fuels challenge (2020)[52]	Carbon dioxide conversion, hydrogen production, and AI-accelerated materials discovery
Global	Mission innovation (2021)[53]	Net-zero, resilient, and people-centred cities (urban transitions mission); carbon dioxide removal technologies (carbon dioxide removal mission); cost-competitiveness of clean hydrogen (clean hydrogen mission); ability of power systems in different geographies and climates to effectively integrate up to 100% variable renewable energy (green powered future mission); cost-competitive solutions for the efficient decarbonisation of hard to abate energy intensive industries (net-zero industries mission)
India	Smart cities mission (2015)[54]	Cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'smart' solutions
Japan	Realisation of sustainable resource circulation to recover the global environment by 2050 (2020)[55]	Solutions to global warming and environmental pollution through realisation of sustainable resource circulation for the global environment
Norway	PILOT-E (2016)[56]	New, environment-friendly energy technology products and services: zero-emissions maritime transport (2.0), zero-emissions land-based goods transport, the energy system of the digital age, sustainable industrial processes for the future, a zero-emissions hydrogen value chain, zero-emissions construction and facilities
Norway	Pilot-T (2021)[57]	Novel, smart mobility solutions with the potential to contribute to the creation of an efficient, safe, and environment-friendly transport system for the future
Norway	CLIMIT (2005)[58]	Carbon capture and storage technologies (CCS): full-scale CCS value chain in Europe, large-scale storage of

[51] https://www.csiro.au/en/about/challenges-missions/Hydrogen

[52] https://nrc.canada.ca/sites/default/files/2020-11/mcf-brochure-e.pdf

[53] http://mission-innovation.net/

[54] https://smartcities.gov.in/sites/default/files/SmartCityGuidelines.pdf

[55] https://www8.cao.go.jp/cstp/english/moonshot/sub4_en.html

[56] https://www.enova.no/pilot-e/information-in-english/

[57] https://www.forskningsradet.no/en/call-for-proposals/2022/pilot-t/

[58] https://climit.no/en/

Country (or multi-country region)	Mission policy title (& year initiated)	Definition of relevant mission area(s)
		CO2 on the Norwegian shelf in the North Sea, future solutions for CCS
United Kingdom	Industrial strategy challenge fund (2017)[59]	Industrial decarbonisation; low-cost nuclear; digital technologies for a flexible, more productive and sustainable manufacturing sector; smart local energy systems; smart sustainable plastic packaging; production of resilient and sustainable food; developing technologies to reduce energy and resource use within the foundational industries
United States	Energy Earthshots (2021)[60]	Cost of clean hydrogen (hydrogen shot), cost of grid-scale energy storage for systems that deliver 10+ hours duration (long duration storage shot), cost of carbon dioxide removal and storage (carbon negative shot), cost of enhanced geothermal systems energy (enhanced geothermal shot), cost of floating offshore wind energy (floating offshore wind shot), cost-competitiveness of industrial heat decarbonisation technologies (industrial heat shot)

Figure 21. Overview of related mission policies and their respective mission areas in non-EU countries

Source: Authors

The comparison with MOIP outside the EU reveals that most missions target (hard-to-abate) industries rather than cities and adopt a more sectoral approach vis-à-vis the orientation towards holistic, placed-based innovations in the climate-neutral and smart cities area. Moreover, missions vary in terms of their openness to different technological solutions but place much greater emphasis on the development of new technologies and demonstration of tangible, industrially scalable outcomes. **The mission area climate-neutral and smart cities requires a more demanding MOIP of a transformative rather than acceleratory type**, which may involve also major changes in everyday life, governance, and business that overcome rather than renew industrial societies (Wittmann et al., 2021). This broader perspective is in line with the results of a recent stakeholder consultation on the priorities to be taken in governmental research funding towards achieving deeper emission reductions by 2030 and a climate-neutral economy by 2050. The consultation suggests that R&I is needed across a broad spectrum well beyond the energy and industry sectors, including mobility, buildings, and socio-economic and behavioural research. According to European stakeholders, governments should give comparatively less priority to funding research of hydrogen, carbon capture storage technologies, and digital technologies (Sollazzo et al., 2020, p. 71).

[59] https://www.ukri.org/what-we-offer/our-main-funds/ukri-challenge-fund/

[60] https://www.energy.gov/policy/energy-earthshots-initiative

5.4. Key lessons from the review of the mission area

The decision to launch a mission in the area of climate-neutral and smart cities is significant and timely because many cities have already defined ambitious climate targets and long-term visions but are confronted with an 'implementation gap (Hofstad et al. (2021), Huxley et al. (2019) and difficult challenges that they will not be able to address on their own (Gordon & Johnson (2018), Huovila et al. (2022), Webb et al. (2023)). Compared to previous, mostly sectoral initiatives, a MOIP approach has the potential to ignite more impact- and goal-oriented actions in cities that cross R&I and other action fields. **The mission area represents an exemplary effort of connecting mission-oriented innovation policy with place-based approaches to innovation and the principle of subsidiarity (**Wanzenböck & Frenzen (2020), Schwaag Serger et al. (2023)). However, the review presented in the previous sections shows that cities have also become more vulnerable to transnational and global trends that put local transformation processes at risk. Mission-oriented innovation policy, with its focus on bottom-up governance and innovation processes, will thus likely need to be complemented with significant efforts at the regional, national, and EU level.

Locating the mission area 'climate-neutral and smart cities' in a global context shows that **it differentiates significantly from most MOIP in the domain of climate neutrality by inviting a far more holistic and systemic approach to innovation processes**. The mission area addresses some of Europe's main challenges in achieving climate-neutrality that lies beyond the scope of most missions launched in non-EU countries. This is, notably, true with respect to critical domains where less progress has been achieved to date such as urban transport, buildings, and land-take as well as cross-cutting challenges relating to non-technological issues and lock-ins resulting from the interplay of urban subsystems. This opens possibilities for truly transformative changes at the city level that can generate cascading effects across all sectors. Being high on the global agenda (Seto et al., 2021), **the focus on climate-neutral cities could put the EU in a leadership position in the provision of systemic and cross-sectoral solutions.**

Building on previous initiatives at the city level and in transnational city networks, the mission area was instrumental in mobilising stakeholders across governmental bodies and civil society organisations. Overcoming departmental siloes and establishing linkages across different governmental levels is essential to making urban transitions to climate neutrality possible.[61] The mission area attracted considerable interest among cities and inspired several Member States to introduce new policies and city administrations to reorganise their departments. The mission area was an effective 'boundary object' (Janssen et al. (2023) for mobilising many important, if not all, actors needed to realise a climate-neutrality in cities.

While broadly framed to enable systemic innovation and compatible with established initiatives towards climate-friendly and smart cities, **the definition of the mission area comes at the cost of a rather technical jargon and unclear communication of benefits for citizens**. By contrast, the emphasis on cost reductions and cost-effectiveness makes many mission areas defined in non-EU countries easier to communicate. At the same time, the mission area conveys a rather technocratic, 'smart' vision of city governance, which may undermine efforts to make citizen involvement a cornerstone of EU's approach to mission-oriented innovation policy. Related to this, the mission area does not account of key urban challenges associated with increasing social and spatial segregation. Notably, some of these issues have been addressed in the urban transitions mission with its focus on 'net-zero, resilient, and people-centric cities'. The formulation of the mission area, however, seems to

[61] See the mission assessment report.

be primarily driven by political concerns of inclusiveness and comprehensiveness rather than conveying the expected outcomes and benefits of the mission.[62] The mission area would likely be different if it had emerged from a citizen co-design or consultation process as opposed to political debates in the European Parliament and European Council[63]. For example, including the notion of 'smart' in the definition of the mission area and in the Cities Mission was evidently a political decision, even though it had not been included in the proposals of experts prior to the selection of the mission area (EC (2018b), EC/Mazzucato (2018)) and was removed by the mission board in its proposed mission[64]. Ultimately, the mission area did not preclude more citizen-friendly formulations of the mission. As the review of mission areas from EU and non-EU countries shows, mission areas frequently use different terminologies than missions. A notable example is the 'healthy, clean cities' mission, which emphasised health and cleanliness while operating within very much the same mission area as the EU's Cities Mission. A more user-centric design approach (Hill, 2022) to the formulation of missions would be a benefit. Respecting the scope of mission areas in technical terms, does not preclude developing missions of high inspirational value to stakeholder groups.

6. Mission area: soil health and food

6.1. The scope and definition of the mission area

After a process in which the European Commission intensively interacted with Member States over the selection of mission areas, 'soil health and food' was one of the five areas that was adopted in the autumn of 2018. Other options on the shortlist of about 20-30 options also covered options of a more technological nature, like quantum and hydrogen[65]. The choice for selecting soil health and food as a mission area fits the imperatives of current views on mission-oriented innovation policy, stating that missions form an opportunity to go beyond boosting R&I and technology development and instead help to tackle actual societal challenges (EC, 2018).

An interviewee underlined that a more specific motivation for selecting this mission area was that **it represents a natural capital dimension for which there has been relatively little policy progress in the EU for a long period. Meanwhile soil health conditions have deteriorated.** Therefore, policy makers from various domains (including agriculture) strongly advocated for a mission area that would provide an opportunity to strengthen the awareness and commitment around improving soil health – notably by catalysing or even being a fundament under other EU-level policy developments in the domain of soil health and food. More specifically, the soil health and food mission area was supposed to provide building blocks (like a monitoring infrastructure) for Green Deal strategies and concrete policies like the Soil Strategy and the Commission's proposal for a Soil Monitoring Directive that were already in early stages of development (EC, 2020). As also stated in the 2022 SRIP report: "R&I is essential for adapting our territories, food, water systems, infrastructure, and our ways of producing and consuming" (EC, 2022, p149), for instance when it comes to providing

[62] For example, the 'healthy, clean cities' initiative aimed for climate-neutral cities but stressed the benefits in terms of health and cleanliness instead, similar to the mission areas on oceans and soil (EIT Climate-KIC, 2020).

[63] For an overview of how various initiatives arrived at their definitions of missions, see Larrue (2021). In the context of EU missions, co-design workshops with citizens were held after the mission area had been defined.

[64] The mission selection process is assessed in the mission assessment report.

[65] Source: interviews with EC officials.

accurate information that allows for monitoring the evolution of soil (health) evolution. A particular motivation for taking soil health and food as a topic requiring a mission approach is that while there were actual and forthcoming policies (at the EU and national level) dealing with soil health, much of these efforts were fragmented and only consider a subset of soil health indicators (e.g. only land degradation or erosion, but not biodiversity). One prominent mission could not only provide knowledge and infrastructure inputs for those separate policies, but also align them better and accelerate their visibility and uptake (Bouma, 2022).

Just like for the other mission areas, a mission board consisting of 15 experts was installed in August 2019. The mission board for soil health and food was asked to analyse the mission area and, consequently, propose a concrete mission (for more on the mission itself see the mission assessment report for soil health). This led to the publication of the 'Caring for soil is caring for life' report in September 2020 (EC, 2020).

Together with the Joint Research Centre (JRC) the mission board conducted a review of the latest literature on soil health and food. The main conclusion was that "current management practices result in, approximately, 60-70% of EU soils being unhealthy, with a further, as yet uncertain percentage of soils unhealthy due to poorly quantified pollution issues. A 75% goal of healthy or improving soil by 2030 through a radical change in current land management practices is both feasible and necessary. Soils will also benefit from improvement to indirect drivers of change such as reductions in air pollution and carbon emissions." (EC, 2020, p.34). More specifically, the review points at several specific challenges. These are listed in Figure 22; the provided quotes and sources supporting the provided evidence can be found in Annex 1 of the mission board report ('Review of the evidence base: status of soil health across Europe 2020').

Specific challenges	Evidence for the specific challenge (illustrative excerpts)
Nitrate	"The Gross Nutrient Balance Indicator (EUROSTAT 2020) shows that there is currently an excess of fertiliser applications in the EU" "SOER 2020 (EEA) reports that for 65-75% of agricultural soils, nitrogen values exceed critical values beyond which eutrophication can be expected"
Organic carbon	"LUCAS Soil data, covering surface soil, show that cultivated and permanent crops have the lowest SOC concentrations of all major land cover classes"
Peat	"Peats cover 8% of EU land area, of which 50% of peatlands are estimated to be drained which will result in the oxidising of the peat and loss carbon to the atmosphere (JRC 2016)."
Water erosion	"Pangos et al. (2015) reports that 24% of land has unsustainable soil water erosion rates (>2. t /ha)." "a new report by JRC (Panagos et al. 2020) shows erosion by water on arable land is 10% greater than the mean for the EU"
Compaction	"The best available estimates suggests that 23% of land assessed had critically high densities (JRC 2016)."
Pollution including risks to food	"In terms of local soil pollution, JRC (Paya Perezet al. 2018) reported 2.8 million potentially contaminated sites"

Specific challenges	Evidence for the specific challenge (illustrative excerpts)
Soil sealing and net land take	"Artificial areas cover 4.2% of the EU (EUROSTAT 2017) of which about 50% is sealed" "The rate of net land take was estimated to be around 539 km² per year during the period 2012-2018 (EEA 2019)"
Salinisation	"In 2016, 10.2 million hectares was actually irrigated (5.9 % of EU). 25% of this area is at risk of secondary salinization i.e. 1.5% of EU"
Desertification	"The most recent estimate of sensitivity to desertification in Southern, Central and Eastern Europe in 2017 suggested 25% (411.000 out of 1.7 million km2) was at High or Very High Risk"
Soil biodiversity	"It is likely that all of the above drivers are probably singly or in combination resulting in a decline in biodiversity but there are no actual EU data demonstrating soil biodiversity change"

Figure 22. Evidence base for the mission area – soil health and food

Source: EC (2020).

The environmental and societal consequences of deteriorating soil health conditions are not to be underestimated. Defining soil health as "continued capacity of soils to support ecosystem services", the mission board for soil health and food (EC, 2020, p.8) stressed that improving soil health is crucial for safeguarding the following ecosystem services:

- producing adequate nutritious and safe food, feed, fibre and other biomass for industries;
- storing and purifying water, regulating flows, recharging aquifers, and reducing the impact of droughts and floods thereby helping adaptation to climate change;
- capturing carbon from the atmosphere and reducing emission of greenhouse gases from soils, thereby contributing to climate mitigation;
- nutrient cycling supporting crop productivity and reducing contamination;
- preserving and protecting biodiversity of habitats both above and within the soil;
- supporting the quality of our landscapes and greening of our towns and cities.

The mission board underlined the potential contribution of a mission in this mission area to the UN's SDGs targets. Those most directly affected by soil degradation, and thus requiring soil action, are SDG 2 (zero hunger), SDG 6 (clean water and sanitation), SDG 13 (climate action) and SDG 15 (life on land)[66]. These are aligned, to a large extent, with the SDGs targeted by the European Green Deal that was adopted around the same time as the mission board was preparing its report. A comprehensive overview of SDGs affected by healthy soils

[66] The mission board noted that the topic of soils was hardly mentioned in targets for the SDGs. To highlight that soil health is a transversal concept, the board proposed a set of soil indicators for 11 SDGs.

and the ecosystem services they render was proposed by a team led by the Food and Agriculture Organisation (FAO) and involving the European Commission; see Figure 23.

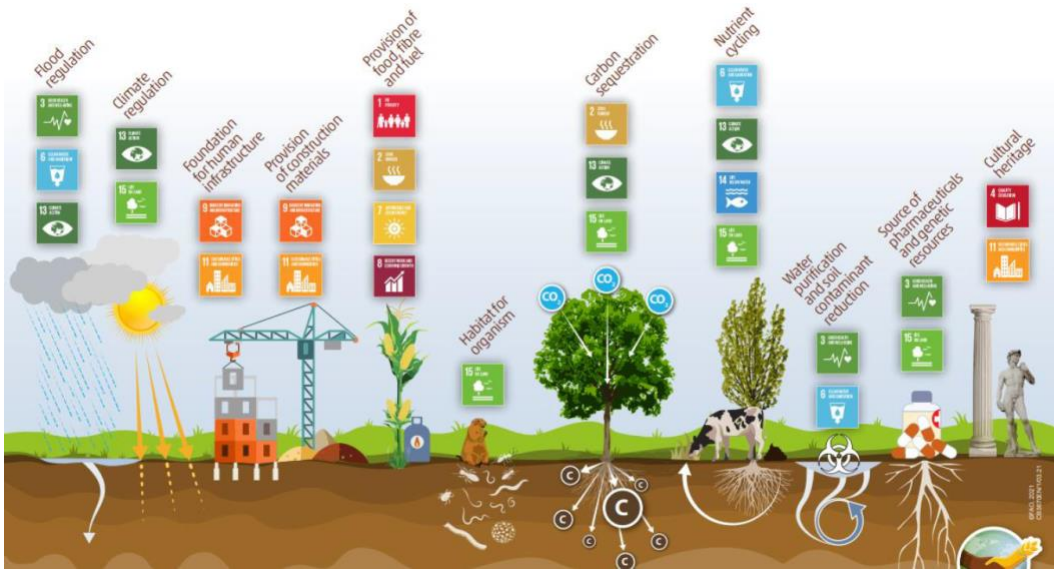

Figure 23. Ecosystem services and SDGs supported by healthy soils

Source: FAO, 2020

6.2. Review of the mission area

6.2.1. The role of R&I in addressing the challenges

A first basis for reviewing the mission area is determining whether R&I make a meaningful contribution to solving societal challenge(s). Obviously non-R&I policies can often make a tremendous difference but given that the EU mission policies are rooted in Horizon Europe it would be problematic if only other policies matter. Indeed, it is part of the MOIP concept that they should have ambitious goals (regarding pressing societal challenges) that can only be achieved by the development and application of novel solutions. Of particular interest are solutions that are not stand-alone products, services, etc. for which there are markets, but solutions that require the transformation of entire production-consumption systems (Hekkert et al, 2020). Such transformations often rely on a range of complementary investments and efforts by different actors (including users), targeted at knowledge development as well as infrastructure, legislation, awareness raising, and any other factor that determines the possibility for new solutions to be adopted. If many factors need to change simultaneously to create the synergies that foster system transformation, it is essential to bundle and coordinate packages of R&I (and non-R&I) policies. This is where missions, as coordination devices, hold an important promise (Janssen et al, 2021).

The question here is thus to what extent soil health and food forms an area in which a mission approach (with a clear R&I component, and more) can indeed make a difference. Empirical evidence shows that technology can play an essential role in mitigating the harmful impacts of industrialisation on the environment and achieving SDGs (Ahmad et al., 2020); and that R&I is a mechanism to mitigate air and soil pollution (Alvarado et al., 2021). Moreover, the promotion of pro-poor and pro-farmers soil and water conservation measures will be essential to support adaptation to climate change (File and Derbile, 2020). It follows that R&I policy will have to work hand-in-hand with instruments such as the European Agricultural Fund for Rural

Development (EAFRD) or the LIFE programme, promoting agronomic and organic practices in soil and water conservation as a viable option especially for smallholder farmers. However, despite the claims on the necessity to implement a R&I-led model of sustainability and circularity in the European economy, there are some concerns regarding the orientation of recent research activities sponsored in the EU. Muscio and Sisto (2020:10) look at data related to the amounts of money allocated and the projects funded for R&I projects with the EAFRD and the FPs in the agri-food sector. They find that "*the issue of circularity, while widely trusted in policy papers, plays a marginal role in R&I activity. The R&I issue becomes particularly critical if we consider that the global circularity gap is widening instead of shrinking. Therefore, to reverse this negative trend embedded deep within the 'take-make-waste' tradition of the linear economy, a strong need exists for change and for the adoption of transformative and correctional solutions*".

The food and drink industry is the EU's biggest manufacturing sector in terms of jobs and value added. It is also one of the most resilient sectors in terms of economic performance. Food innovations are a priority in continuously evolving food systems and innovations improving soil health rank high among specific food innovations likely to be available to consumers within 5 years (Zickafoose et al., 2022). R&I activity on soil is thriving, with several new trends emerging, such as precision agriculture and the implementation of Agriculture 4.0 and Industry 4.0 technologies in farming (Aubert et al., 2012). However, R&I in agriculture has many peculiarities and policymakers need to account of farmers' entrepreneurship and the need to create an entrepreneurial environment as an indirect way to support the adoption of new technologies and practices.

Innovation adoption is indeed a main concern in the literature dealing with healthy soil. R&I in the agricultural sector, the primary focus of the EU Soil Mission, has a long history (Olmstead and Rhode, 2008). However, innovation is primarily developed 'outside' the agricultural sector and farmers tend to be innovation adopters of technologies developed by the chemical, mechanical or ICT industry. Therefore, innovation adoption is a key aspect of R&I policy in healthy soil and the investigation of the factors influencing the adoption of innovations such as appropriate climate-smart agriculture practices (Kangogo et al., 2021), is a key concern in Europe and elsewhere (see: Mao et al., 2021; Thinda et al., 2020).

In Europe, there is great interest in the '4 per 1000' initiative[67], pushing for soil organic carbon sequestration (SOC) and many regional bodies and organisations have committed to its ambitious aims. SOC sequestration could be a valuable tool in offsetting GHG emissions and improve food quality and adaptation to climate change. However, as noted in Rumpel et al., (2020:357): "*the potential of soils to sequester SOC is limited by biophysical, socio-economic and political barriers. These need to be overcome by region-specific actions and the development and implementation of innovative technologies. […] priorities will need to be decided to ensure that actions are focused on sites and conditions where opportunities to increase soil carbon stocks are most likely to be successful. We conclude that the 4p1000 Initiative is likely to facilitate findings from site-specific studies, practical experiences and model predictions to be incorporated into future policy actions to encourage long-term adoption and implementation of sustainable development strategies*".

Some support can come from the gradual growth of organic farming (Dudek and Wrzaszcz, 2020). However, even organic farming, in order to be economically sustainable needs to rely on innovation is fields such as ICT (Clark, 2020), confirming the transversality of R&I policies supporting soil. The role of intermediary stakeholders, especially from the private sector (e.g.

[67] The 4 per 1000 Initiative was created with the goal of achieving an annual growth rate of 0.4% in soil carbon stocks (or 4‰ per year) in the first 30–40 cm of soil.

crop advisers), will be fundamental in spreading information among farmers about conservation practices, promoting innovation adoption (Eanes et al., 2019).

Finally, a lack of diffusion of innovative soil management practices is more salient than the development of those practices. Hence, there is an interest for promoting healthy soils by applying living labs as a policy instrument. While living labs have been implemented for quite some time, they still have not convinced the academic community of their validity as a policy instrument, at least not at the aggregate level. As noted in Paskaleva and Cooper (2021: 102311): "*despite their 20-year history, the operationalisation of and outcomes from Living Labs are still poorly understood owing to paucity of published evidence, compounded by inadequate research design and insufficient attention to implementing and reporting performance evaluations*".

In addition to the results from the literature review, Figure 24 below sums up some expected contributions of R&I to addressing the mission area challenges.

Specific challenges	Expected contribution of R&I
Practices for enhancing soil health cannot be readily applied, as they have to be tuned to place-specific circumstances	Co-creation and demonstration of knowledge and innovation in living labs and lighthouses, in which different types of stakeholders work together and learn from each other
Practices for enhancing soil health are not adopted when policy makers try to impose them	"LUCAS Soil data, covering surface soil, show that cultivated and permanent crops have the lowest SOC concentrations of all major land cover classes"
Different countries use different (or no) indicators for monitoring soil health aspects	Development, validation, harmonization and integration of indicators, as well as methodologies for measuring them
Experiments with (innovative) soil management practices lack robust methodologies for assessing effectiveness, and/or indicators cover only some dimensions of soil health	"Pangos et al. (2015) reports that 24% of land has unsustainable soil water erosion rates (>2. t /ha)." "a new report by JRC (Panagos et al. 2020) shows erosion by water on arable land is 10% greater than the mean for the EU"
For some soil health problems (like biodiversity decline) or solutions (like biowaste innovation), there is a shortage of applicable insights and techniques	Development of 'technical' knowledge on soil science issues
Practices for enhancing soil health remain underutilised as they are or seem not to be economically feasible	Development of knowledge on socio-economic factors like business models
Practices for enhancing soil health remain underutilised as potential users are not familiar with them	Development of capacities (advisors, education) that support the absorption and application of relevant knowledge

Figure 24. Expected contribution of R&I to addressing the mission area challenges

Source: Mission board for soil health and food (2020) - Caring for soil is caring for life.

6.2.2. Developments influencing the mission area

In the few years since the mission area was defined, the trends in factors impacting soil health and food have varied. A first way to assess these trends is by looking at developments in the societal challenges the mission area addresses. EUROSTAT[68] monitors progress towards the SDG targets including the four SDGs for which there is the strongest link with soil health and food (see section 6.1). The data gives a mixed picture. In the context of agricultural soils, notable positive developments concern the rise in areas under organic farming as well as the reduction of agriculture-based ammonia emissions and severe soil erosion by water. Other highlights are the increases in the share of forest areas and, even more significantly, in terrestrial protected areas. Also overall land degradation (not confined to agricultural land) is in a better position than five years ago. There is no data available for the soil sealing index. The progress on those indicators indicates that, in a number of respects, soil health seems to be gradually improving already. On the other hand, there are also several more concerning developments – both when it comes to the health of the soils themselves as well as of the organisms that live in/on it. Worrying trends are observed for, for instance, the use of hazardous pesticides; nitrate in groundwater; phosphate in rivers; common farmland birds and birds and butterfly biodiversity in general; and greenhouse emissions from land use, land use change and forestry. These trends suggest that there is still plenty of reason to keep investing in a soil health and food mission area.

A second way of assessing the relevance of the mission area is by considering the range of factors, including policy, social, environmental, technological and geopolitical factors that could influence the need of policies for soil health and food. Interviewees have identified several factors, and how these would impact the potential added value of the mission area (Figure 25). One example of such a factor, supported by evidence discussed in the 2022 SRIP report, is the geopolitically driven demand for food security and food system resilience, increasing the pressure on food production on European soils (EC, 2022).

Type of factor/trend	Short summary of the expected impact of the factor/trend
Environmental: Worsening of biodiversity decline, global warming (drought), extreme weather conditions, etc.	Urgency to improve the health of soils increases
Social: Increasing preferences for locally produced healthy food	More local food production puts more pressures on soils, underlining the demand for policy intervention
Geopolitical: The EU seeks to be less dependent on other countries, including when it comes to food production	
Policy: CAP might be adapted after the current period (2021-2027) ends, in a way that it better rewards ecosystem services	More rewards for ecosystem services would probably result in more healthy soils, thus reducing the urgency for the mission area
Technological: Rise of synthetic food production, replacing biological/organic food production	Societies would rely less on agricultural use of soils, potentially lowering soil health challenges

[68] See: https://ec.europa.eu/eurostat/web/sdi/overview

Type of factor/trend	Short summary of the expected impact of the factor/trend
Economic: Globalising food chains, supported by highly industrialised forms of agriculture	Negative impacts for environmental and food quality (and thus human and animal health) and more risk of infectious diseases spreading easily, both aggravating the need for policy intervention
Economic/Technological: Rise of solar panel farms on fertile grounds	Both negative and positive impacts on soil health are possible

Figure 25. Identified factors or possible trends influencing the mission area, in order of descending likelihood.

Source: authors based on interviews and EC (2020).

The conclusion is that the urgency to address soil health and food is becoming more pressing, as almost all the identified factors point in this direction. One exception is found in technological developments like the rise of synthetic food production but given the widespread and deeply rooted preference for organic meat and vegetables this is not regarded as something which will to a large extent replace, rapidly, current ways of producing food. Generally it is regarded as unlikely that scientific and technological breakthroughs will, in the near future, make the mission area less relevant. This has to do with two fundamental aspects of the mission area:

- many suitable innovative and non-innovative practices for improving soil health are already available but simply under-used (due to potential users not being familiar with the potential benefits of those practices and with ways to apply them); and

- Soils differ in many ways across territories and are used in various different ways, therefore requiring rather place-and use-specific practices.

Both aspects reduce the likelihood of a new technology emerging (outside the Horizon Europe actions supported by the mission) that radically simplifies the possibilities for transitioning to healthy soils. Similarly, interviewees remark that ideally the Common Agriculture Policy (CAP) will be reformed in a way that it provides more incentives to land managers to improve the health of their soils. While this would be very welcome, it is not expected to be a very plausible scenario due to the massive interests associated with how CAP funding gets allocated. Moreover, the mission itself might enhance momentum for CAP adaptations, which would imply this would not be an exogenous development impacting upon the relevance of the mission area.

Looking at trends that are seen as more likely to occur, especially various worrying environmental developments are (according to most interviewees) underlining the importance of sustaining or even augmenting support for the soil health and food mission area. Obviously, the overall sentiment is not surprising given that all interviewees themselves are active in this domain. Still, as one interviewee pointed out, the mission can be regarded ‘future proof’ when realizing that known soil health issues have existed and been recognized for various decades, yet without leading to a successful response. In 1979-1980 a ‘soil charter’ was published that addressed a couple of concerning issues. Experts reviewing the soil charter a few years ago concluded that the same problems were still there, only more urgent due to e.g. more intensive farming and accelerated climate change. Hypothetically soil health and food would become a less problematic area if food production was industrialised and centralised, while simultaneously also drastically improving its environmental impact.

According to interviewees this is not to the case, which is one reason for a growing interest in concepts like circular agriculture. More small-scale food production implies that more soils have an agricultural use and will face challenges related to e.g. emissions and pollution.

Moreover, as the mission area addresses other forms of land use, improvements in the health of agricultural soils alone are not sufficient. Urban soils and lands used for forestry face soil health challenges as well. A trend that is hard to interpret is the rise of solar panel farms, or solar parks, on soils that might provide a range of ecosystem services. Recent studies find both negative and positive effects, depending on the indicators used (Choi et al (2020); or Lambert et al. (2021)). More research on models in which solar parks and soil health improvement can be combined as it is telling that current market conditions sometimes value fertile soils so little that it is attractive to cover them with solar panels.

6.3. Restoring soil health: insights from international examples

Governments around the world are looking into the potential of using a mission approach to targeting societal challenges that require innovative solutions. Many of these initiatives are captured by the OECD STIP Compass dashboard on MOIP[69]. None of the listed examples focus explicitly on the area of soil health and food: mission areas (or themes) address either food related topics like food security, or topics that aim to enhance environmental sustainability. The combination of these types of issues seems to be rather rare.

Another common element is that missions tend to target technology domains instead of societal challenges. While this is not consistent with some of the views on what missions are or should be, it is understandable from the perspective that traditionally MOIP were a form of R&D, industrial and innovation policies geared towards boosting economic growth (Mazzucato, 2018). This background is also reflected in the cases in the dashboard by the OECD, as it covers mission-oriented policies that are typically initiated by science or economy/business ministries. For instance, Japan has a rich history of developing elaborate industrial strategies, which can explain why its Cross-ministerial Strategic Innovation Promotion Program (SIP) focused on 'Technologies for smart bio-industry and agriculture'. Similarly, the more recent Moonshot Research and Development Program contains a mission area on the 'creation of the industry that enables sustainable global food supply by exploiting unused biological resources. Those mission areas can potentially give rise to innovations that improve soil health, but it's not embedded in how they are framed. Mission areas that have soil health (and food) more at the heart of their scope can probably be found when looking beyond the science/economy-based 'umbrella frameworks' with multiple mission themes and instead consider missions led by a sectoral ministry. For example, the Agriculture and Agri-Food department of the Government of Canada is looking into the formulation of missions that address the societal challenges this department is responsible for. To what extent this will give a prominent place to soil health and food is still unclear at this stage.

To benchmark the EU mission area against a similar area from outside the EU, relevant comparison material can be found in the Australasia region. A recent publication by Klerkx et al. (2022) describes which technological, economic, societal and policy developments are taken into account in considerations regarding how to use missions for driving agri-food innovation in New Zealand. The authors study the National Science Challenges, established by the Ministry of Business, Innovation and Employment in 2014, and conclude that "challenges such as fragmentation, lock-in of current systems and legacy policies, and limited

[69] https://stip.oecd.org/moip/

attention to exnovation[70], are still standing in the way of enacting a truly mission-oriented" agri-food innovation strategy. They suggest that a coherent mission-oriented strategy would benefit from more attention to (amongst others) capacity building; stronger direction setting from central and local government; and intensified use of dialogues with different stakeholders. As the study examines to what extent the agri-food innovation system is already mission-oriented, and able to transform instead of only strengthen existing ways of producing and consuming, the article has little to say about the background and scoping of a particular national mission area (nor about the use of methods that were used in the process of defining such an area).

More informative in that respect is probably another recent study, on the development of mission arenas in Australia (Fielke et al, 2022). The authors combine the approach of mission-oriented innovation systems with the responsible innovation literature. Whereas the former is obviously directly related to missions, the latter is concerned with making innovation more responsible, inclusive and reflective, particularly on its social and environmental impacts. They apply this framework to the case of the Australian agri-food innovation system, which differs from the European one in some respects.

Firstly, there are no clear overarching MOIP (top down), so actors develop their own missions (bottom up), something the authors coin as "informal mission development", involving actors' recognition of innovation as "a collective social process" (p.6). They refer thus to "emerging mission (and mission like) activities in the Australian agri-food sector" (p.7), where involved actors need to act in concert "to define challenges, develop, deploy, and achieve" (ibid.) collective missions. Thus, whereas there are challenges identified by government agencies such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) agency's goal to "achieve sustainable regional food security and grow Australia's share of premium AgriFood markets"[71] or the National Agricultural Innovation Agenda, these are supplemented by industry associations' own goals and roadmaps. CSIRO identified its challenges and missions through trend modelling/forecasting, stakeholder consultation (including government and academia) and review of Australian and international priorities like the SDGs. In other cases they seemed to be defined by businesses themselves.

Secondly, what seems to unite all of these informal agri-food missions is a primary focus on economic rationales such as increasing production and further establishing Australia's role as exporter of agricultural products, with a secondary focus of also assuring environmental sustainability. Compared to a focus on soils in general, this focus is thus narrower in the sense of being limited to agricultural soils. On the other hand, it can be seen as broader since it looks at agricultural innovation in general, thus including developments which might move beyond the use of soil. The different scope probably stems from the strong influence of the business sector. The Australian agri-food sector is "proudly one of the least subsidised in the developed world (Fielke et al., 2022, p.3), implying that in the context of agricultural innovation coordination and collaboration are traditionally less prevalent than competition.

To overcome issues of fragmentation and growth-focus, the authors suggest developing a cycle (Figure 26) in which people and organisations with 'responsible innovation potential' (considering a broad range of societal values, not just growth) engage in the determination and prioritisation of challenges. This in turn is an input for mission development and based on the results, the cycle can be repeated (starting with broad stakeholder engagement).

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[70] "Exnovation refers to the stopping or abandoning of an innovation, and it is the opposite of innovation. It is often used to describe the discontinuation of a product, service, or technology previously seen as innovative."

[71] https://www.csiro.au/en/about/challenges-missions/Challenges

Figure 26. A mission-oriented innovation cycle

Source: Fielke et al., 2022, p.1

Overall, a clear communality in the articles on New Zealand and Australia is the call for more stakeholder engagement and dialogues during both the formulation of mission areas as well as the implementing and execution of policies fitting the corresponding mission. While there is no basis to state whether this was done worse/better or insufficiently/sufficiently in the case of the EU mission area on soil health and food, it seems relevant to take these recommendations to heart when (re)considering existing or new mission areas.

6.4. Key lessons from the review of the mission area

The overall conclusion, arising from the desk research and interviews, is that the mission area is defined and scoped in a way that is flexible when it comes to responding to technological, societal, economic and policy developments. The 'soil health' part of the mission area's scope is on the one hand specific and recognisable, while on the other hand it is a transversal concept cutting across many societal challenges. 'Food', which is the second part of the mission area's scope, is just one specific domain and relates to various societal needs, e.g. those pertaining to food health and food security. Beyond that, soil health also covers challenges related to, amongst others, the health of people living on and eating from soils, the capacity of soil to purify and retain water, and the possibility of soils to be used for carbon sequestration (important for limiting climate change) and cycling nutrients. This broad scoping makes it unlikely that the mission area becomes irrelevant, as emerging technologies and policies might (partially) tackle some challenges but not all. According to interviewees, all of the aforementioned issues are likely to become more urgent, thereby underlining the importance of a mission that tackles them while acknowledging the interdependencies between those challenges and associated societal values. The strength of the mission area scope lies in recognising that the various challenges are interrelated, and that there is no use of only targeting e.g. problems related to water or contamination issues if that intensifies other problems. Instead, the integrative scoping of the mission area encourages experimentation with policies and solutions that address multiple challenges at once.

In sum, there are no findings suggesting a need to recommend adjustments to the mission area. The only potential downside is that while focusing on a broad overarching notion like soil health allow to address many challenges, it prioritises or highlights none of them. A potential consequence is that the soil health label as such is not regarded as an important topic by those who are not familiar with what it entails. Obviously, this is precisely what the mission itself is trying to tackle in various ways (see the mission assessment report). However, a critique is that such attempts are somewhat hindered by the fact that soil health does not sound as alarming as other more familiar societal challenges related to e.g. cancer or climate change. Water and biodiversity related issues are also covered by the mission area, but in a relatively implicit way. So although technically they fall fully within the mission area's scope, a case could be made for defining the mission area (or mission) in such a way that it directs more attention to some increasingly urgent but relatively unnoticed societal challenges. Then again, given that stability and clarity are fundamental for MOIP, it is not recommended to alter the mission area definition at this stage. It would be more logical to ensure that the envisaged communication efforts of the mission sufficiently highlight less well-known but critical issues like biodiversity decline, and that these efforts target an audience that currently is insufficiently aware of this while being able to foster change (including EU level policy officials and European Parliament members).

7. Conclusions and policy options

7.1. Cross-cutting findings

This study has reviewed the current and future policy relevance of the five mission areas. As described in each mission area chapter, as well as in the related mission assessment reports, the mission areas were identified and agreed by the co-legislators (the European Council and European Parliament) in the Horizon Europe Regulation. The mission areas, defined in only a few words in the regulation, were further explored and developed by the mission boards with the support of foresight studies and broad consultations with stakeholders and citizens. The five mission assessment reports, prepared by the study team, have concluded that the scoping of the mission areas and the design of the mission objectives and plans have been, generally, well managed in an open and transparent manner and based on the available scientific evidence. Stakeholders consulted appreciate the way the mission area has been developed into a set of objectives and actions to deliver on the agreed mission goals.

How well does the definition of the five mission areas address the major challenges the EU faces?

A first observation is that the concept of a 'mission area' is not defined in an official EU document. A mission area can be thought of as equivalent to a 'grand challenge', which Mazzucato et al (2019) defined as "*a difficult but important, systemic and society-wide problem with no 'silver bullet' solution*" (also termed a 'wicked problem'). The 2017 ESIR memorandum (EC, 2018) noted that "*the overall SDG-framing of a mission-oriented approach must be situated within an EU policy agenda built on European values. The EU can drive a policy "frontier" which is at the same time more actionable and more ambitious than the overall SDGs. Obviously not all SDGs can be addressed through R&I policy, nor can they be achieved through just EU policy*".

In contrast to the lack of an official definition of mission area, the Horizon Europe Regulation defines a mission as "*a portfolio of excellence-based and impact-driven R&I activities across disciplines and sectors, intended to: (i) achieve, within a set timeframe, a measurable goal that could not be achieved through individual actions; (ii) have an impact on society and*

policy-making through science and technology; and (iii) be relevant for a significant part of the European population and a wide range of European citizens". Mazzucato et al (2019) offered a more concise definition of a mission as a "*concrete target, achievable step towards a grand challenge that contextualises projects*".

In the introduction to the foresight reports prepared for each mission board, it was, noted that "*Within each of these Mission Areas, a limited number of specific missions shall be defined*". Hence, a mission area may potentially require more than one 'mission' to solve a systemic challenge. Each mission may, following the definition, set objectives ('a measurable goal') which have the potential to contribute to solving, the challenge. Indeed, the OECD (2023) note that mission-oriented strategic agendas act as 'collective action frameworks'. They argue that "*the objectives are not the starting point but rather a first result of the mission itself. Many missions start with broad objectives, priorities or mission areas*".

Hence, the first step of a mission is to develop or refine the objectives, most often embedding them in a strategic agenda or roadmap. The five EU Missions followed this process with the mission boards asked to devise a strategy with objectives and targets (the mission board reports) and then a plan (the implementation plans).

The dividing line between 'mission area' and 'mission' prove to be 'fuzzy' for many stakeholders consulted during this review, including members of the mission governance structures. The mission areas, defined in a few words, were very broad with no clear direction set by the co-legislators[72]. As the OECD (2023) note "*These loose directional elements do not really aim to set a clear orientation, but rather incentivise and facilitate the formation of large partnerships, wherein public and private actors jointly set attainable objectives and develop the collective strategy to meet them*".

A first question that arises is, therefore, whether the initial definition of mission areas was a sufficient basis for developing the missions. This can be viewed from two perspectives:

- Why these five missions areas? Or, in other words, why are the five selected topics more important than other possible 'mission areas' addressing challenges the EU faces?

- Should, or could, these mission areas have led to more than one 'mission'?

A **first overall conclusion** is that the 'societal relevance' of each of the five 'mission areas' is not contested, either based on the review of the evidence nor by the stakeholders consulted. The table below summarises the challenges and the (principal) SDGs to which the mission areas respond. The five areas address complex challenges facing the EU population that require action on the part of governments, businesses, education and research institutions and civil society groups.

[72] The study team was not able to access documentary evidence on how the five mission areas were selected. Interviewees, including from the EC (mission managers, mission secretariats), were not able to provide insight into how the choice was made before being adopted by the Council and Parliament.

Mission area	Major challenges addressed	Contribution to SDGs
Adaptation to Climate Change, including Societal Transformation	Gaps exist between current levels of adaptation and the levels needed to respond to climate breakdown. Commitment to adaptation in line with EU's treaty obligations (Paris Agreement) and strategies.	SDG 13 – climate action
Cancer	Second leading cause of death in the EU, first cause of death in children older than one year. The EU has less than 10% of the global population but a quarter of all (reported) cancer cases.	SDG 3 – Ensure healthy lives and promote well-being at all ages
Healthy Oceans, Seas, Coastal and Inland Waters	Unsustainable human footprint in the use of (fresh)water resources plus increasing pollution (notably (micro-plastics) of water and putting at peril future ecosystem services Progress in reaching good environmental status in the EU's marine waters has been slow and the 2020 targets of EU legislation were not met	SDG 14 - Life below water SDG 6 - Clean water and sanitation
Climate-Neutral and Smart Cities	Tackling GHG emissions of cities has a high potential to deliver rapid and large-scale contributions to decarbonisation while creating co-benefits with respect to air quality, heat stress, as well as mental and physical health.	SDG 11 – Sustainable cities and communities SDG 13 – climate action
Soil Health and Food	Current management practices result in 60-70% of EU soils being unhealthy Increasing water erosion of soils, soil sealing, salinisation and desertification put at risk capacity to maintain and protect biodiversity and food production.	SDG 2 – Zero Hunger SDG 6 - Clean water and sanitation SDG 13 (climate action) SDG 15 (life on land).

Figure 27. How well do the five mission areas address the major challenges the EU faces?

Source: authors based on references cited in mission area chapters.

Rather than contesting the choice of the five mission areas, the stakeholders consulted tended to discuss the way the scope of the mission area was (re)defined (e.g. the dropping of food to focus on a broader notion of soil health, or the absence of the words societal transformation in the Mission CCA title) when being translated into a mission. The mission

area ‘takes life’ through the set of objectives defined in the mission which provide an explicit scope for the actions to address the mission area.

The option of developing more than one mission for each mission area does not appear to have been considered. Rather the missions defined by the board have tended to adjust the scope of the area (e.g. dropping societal transformation from the adaption to climate change or viewing soil health as being wider than food production). Specific objectives set by the mission boards can to some extent be considered as ‘sub-missions’ which poses the question of whether, over time, some missions might be divided into specific missions (e.g. freshwater resources and marine environments might be considered as linked but with differing challenges and communities of stakeholders).

At the same time, **a second overall conclusion** is that the five mission areas are, to a greater or less extent, interlinked. Climate neutral cities addresses mitigation of (some of the key) anthropogenic causes of climate breakdown; while the Mission CCA promotes a greater focus on adaptation at local and regional levels given the fact that the action taken to date on mitigation is not expected to be sufficient to limit an increase in extreme climate events. Similarly, Soil Mission and Mission Ocean and Waters are closely interlinked with healthy soils being a key factor in maintaining or limiting a further decline in the functioning of hydrosphere. Finally, the prevention of (and recovery from) cancer depends on multiple factors including the quality of the environment (air, water, soil), access to quality and healthy foodstuffs, etc.

The mission areas have been viewed and analysed as distinct topics but the mission boards reports, mission implementation plans, and the opinions expressed by stakeholders (e.g. during the policy workshops organised for this study) underline **the systemic nature of the challenges addressed** and the need to identify and take action to optimise the synergies between the mission areas (or, more precisely, the missions). Two of mission areas address the most complex systems on Earth, the soil substrate[73] (“*which we once saw as a homogenous mass, is composed of structures within structures within structures*”, Monbiot, 2022) and the hydrosphere, on which life depends; two others address how to mitigate or adapt to the breakdown, caused by human activity, of the equally complex climate system. The human body is a fourth complex system addressed by the missions, with the propensity to contract and survive cancer impacted by genetic, social and environmental factors but also by the capacity of social and health care systems to take preventive measures, ensure early diagnosis, test cures and provide care for cancer patients. Possibly, the answer to the question “*why these five mission areas*” is precisely their systemic (wicked) nature.

How important is role of R&I in addressing the mission area challenges?

The role of R&I in addressing the challenges of a mission area is a key dimension determining the translation into a mission. This review has taken stock of the excepted contribution of the R&I for each mission area. A **third overall conclusion** is that need for sustained R&I investment and outcomes is evident for all five mission areas with, however, differences in the extent to which the balance is given to more ‘research’ (new discoveries) to more ‘innovation’ (implementation of existing or novel solutions).

[73] 'Supporting surface' on which an organism grows. The substrate may simply provide structural support, or may provide water and nutrients. A substrate may be inorganic, such as rock or soil, or it may be organic, such as wood.

Mission area	Expected contribution of R&I to the mission area
Adaptation to Climate Change, including Societal Transformation	Scientific efforts are needed to produce new robust evidence tailored to the needs of regional and local authorities as a basis for more effective CCA policies Underdeveloped evidence in the form of space-based information on current and future climate-related hazards, vulnerabilities and risks
Cancer	Cancer prevention research has been insufficiently funded given its potential role in cancer control Unequal R&D activity across R&D stages and between rare and non-rare cancers. Need to increase the translation of research discoveries into therapeutic innovation.
Healthy Oceans, Seas, Coastal and Inland Waters	Research into the interdependencies among the elements of the water-climate nexus including the use of digital technologies for representing the water continuum and supporting a modern ocean-water governance and management system. R&I is required in 'ocean ethics' to increase the awareness of the impact of human-activities, on the status of water ecosystems
Climate-Neutral and Smart Cities	Give greater consideration non-technological innovations and hence the important role of R&I in supporting "system innovation in the whole value chain of city investment". Key innovation challenges to help urban systems in their transition to lower emissions include city management and governance, mobility and energy solutions, adaptations to the built environment, etc.
Soil Health and Food	For some soil health problems (like biodiversity decline) or solutions (like biowaste innovation), there is a shortage of applicable insights and techniques. Improvements in soil health rank high among specific food system innovations likely to be available within 5 years. R&I in agriculture needs to account for and support farmers' entrepreneurial environment as an indirect way to support the adoption of new technologies and practices.

Figure 28. The role of R&I in addressing the mission area challenges

Source: authors based on evidence presented in each chapter

A **fourth overall conclusion** is that the scope of the mission areas should have an increased emphasis on interdisciplinary R&I including a greater integration of social science and humanities (SSH) and a balance between technological and non-technological (social) innovations. This includes an emphasis on encouraging and motivating adoption of 'existing technologies' by specific groups (e.g. farmers, citizens, businesses, etc.). R&I is required to support the development and management of new 'governance tools' (e.g. digital twins) and

for the monitoring of the transformation of the (multiple) sub-systems addressed by the missions.

Are there significant changes to economic, social and environmental trends and factors influencing the mission areas?

The review assessed whether the relevance of the mission areas has changed in the last five years given developments in environmental, economic and social landscapes. Overall, the trends influencing the five mission areas suggest that they are as relevant in 2023 as they were five years earlier (during the process of preparation and adoption of Horizon Europe).

Mission area	Trends impacting the mission area
Adaptation to Climate Change, including Societal Transformation	Frequency and severity of extreme climate events increasing Trend in climate related economic losses is worsening
Cancer	The number of cancer cases will increase by 25% in the EU if no action is taken. Trends in major causes of cancer, e.g. obesity and smoking, are stable or worsening.
Healthy Oceans, Seas, Coastal and Inland Waters	Due to trends in climate breakdown, demographic pressures (water-use, over-fishing), man-made pollution (plastics, nitrates), etc. measures to reduce the impact of human activity on ocean and water ecosystems continue to be a priority
Climate-Neutral and Smart Cities	Projections of future GHG emission trends suggest that existing and additional measures the EU and the Member States plan to launch in the coming years will not be sufficient to reach the goal of reducing GHG emissions to at least 55% (instead of 40%) below 1990 levels by 2030.
Soil Health and Food	Worrying trends, for instance, in the use of hazardous pesticides; nitrate in groundwater; phosphate in rivers; biodiversity; and greenhouse emissions from land use., land use change and forestry. These trends suggest that there is still plenty of reason to keep investing in a soil health and food mission area.

Figure 29. Trends influencing the relevance of the mission areas

Source: authors based on evidence presented in each chapter

Another way of thinking about the question is at what point would the urgency to act in the area be reduced sufficiently that a mission is no longer required. A response is that the 2030 targets set for the missions, are in most cases, 'stretched targets', in the sense that they indicate a 'direction of travel'. The mission assessment reports, while reporting progress in implementing the missions, suggest that there remains a need for sustained action to address the challenges of each mission area. Hence, **a final conclusion** is that the mission areas, as defined by the co-legislators, and further scoped out by the mission boards, appear flexible enough to allow their adjustment to identifiable trends over the coming seven years.

7.2. Options for the future definition of mission areas

As noted above, the initial mission area definition and decision process has not been codified (which is something to avoid from a perspective of good governance) and, therefore, assessing 'ex-post' the choice is a difficult exercise. Should a process of selecting mission areas be conducted in the future (in preparation for framework programme 10 (FP10) and the next multi-annual framework 2028-2034), **a first recommendation** is to consider how to:

- Define mission areas based on an objective evidence-base (including assessment of mega trends, foresight, etc.) so as to avoid a 'bidding war' from a political perspective or undue influence by lobbying groups (researchers, business, etc.)

- Agree openly on the criteria and the procedure for ranking alternative mission areas, including by giving sufficient time and means for citizens to propose ideas that feed into a high-level policy debate and final decision.

These orientations are in line with the four steps for selecting missions proposed by the expert group on the Economic and Societal Impact of Research (ESIR) memorandum (EC, 2018).

As noted, above, the mission areas address complex systems which are at risk of reaching tipping points where the systems collapse or switch into other, non-desirable, states. The missions can be viewed as means of reducing the risk of soil, water and climate systems reaching 'physical' tipping points by fostering, through governance and organisational innovations, 'social' tipping points' (Juhola et al, 2022), where a change in the underlying elements or behaviour of actors triggers a large non-linear response in the social system. Similarly for cancer, while R&I may support the development of new preventative and curative methods, a social tipping point may be required to reduce the causes of cancer such as smoking and obesity.

Hence, a **second recommendation** is that the definition and selection of mission areas (challenges) should be based on a deeper understanding of the social factors driving or hindering change and to identify the social innovations required. Indeed, the 2023 ESIR report noted that "Policymaking needs greater awareness of how to achieve 'unlearning', address lock-ins and overcome inertia of patterns, policies and processes that prevent necessary and desirable change". This requires an enhanced use of relevant SSH research.

A **third recommendation** is that there should be a structured and on-going process of updating the key trends and factors influencing the five mission areas (and, potentially, pre-identification of emerging future mission areas). This study has undertaken a review of trends but had a limited brief and resources to address the multiple factors influencing the mission areas. The societal, environmental, technological, etc. mega-trends require an on-going analysis of new evidence and anticipation (R&I foresight) to provide a basis for the re-assessment of objectives, activities, future Horizon Europe work-programmes and calls, by the missions board, mission secretariats, mission stakeholders.

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This study reviews the current and future policy relevance of the five mission areas. The review underlines the systemic nature of the societal challenges addressed and the need for concerted action across the five areas. The scope of each area is sufficiently broad to stand the test of time to the 2030 horizon addressed by each respective mission. The review makes recommendations for the way in which mission areas should be defined and selected in the future and their continuing relevance monitored.

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