Opinion of the Scientific Committee of the European Environment Agency on knowledge and research needs for sustainability: input to the European Union's 10th Research Framework Programme

February 24, 2026

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Objective of this opinion

As requested by the Executive Director of the European Environment Agency (EEA) according to Art. 10 of the EEA Regulation, this is an opinion from the Scientific Committee on "future knowledge needs to support sustainability in Europe". The background for the EEA request is to have SC input to knowledge production at the EEA and EEA member and cooperating countries as set out in the EEA-Eionet Strategy 2021-2030, supporting the implementation of the European Green Deal add links and the Competitiveness Compass. The opinion also serves as the Committee's input to the EU's 10th Framework Programme on Research and Innovation (FP10).

Background

The EEA Scientific Committee comprises up to 20 independent scientists from EEA member countries, selected through an open process to ensure scientific expertise in areas of importance to the agency's work. According to the EEA Regulation, the Committee supports the Executive Director and the EEA Management Board by providing scientific advice and is required to provide an opinion on the draft EEA Single Programming Document, the Agency's recruitment of scientific staff as well as on any other issue requested by the Executive Director and Management Board.

Acknowledgements

The Committee thanks especially representatives of the European Commission, EU research institutions, European Environmental protection agencies and the EEA for feedback and input to the opinion. The first draft of knowledge needs across priority areas was discussed with representatives from EU institutions, Committee members, and representatives of EEA and Eionet partners in the 92nd Scientific Committee meeting on 29 September 2025 before receiving input from EEA. The opinion was finally adopted at the 93rd Scientific Committee meeting on 24-25 February 2026.

Copenhagen, 24 February 2026

[Signed]

Louis Meuleman

Chair of the Scientific Committee

Introduction: Opportunities for knowledge and research

The triple planetary crisis of climate change, biodiversity loss and pollution continues to threaten the ecological foundations on which European societies, economies and security depend. As demonstrated in the EEA's Europe's Environment 2025 report and indicated in the Commission's proposal for the 10th Framework Programme on Research and Innovation, Horizon Europe (2028 – 2034), future knowledge and research must acknowledge the fundamental dependencies between ecological and societal well-being.

In this opinion, knowledge and research needs are outlined across the core areas of EEA and Eionet: Climate change, pollution, biodiversity and sustainability transformations. Identification of knowledge needs and recommendations for research to address them are formulated across three main areas (and more detailed lists can be found in the annex):

- **Health, pollution, biodiversity and climate change**
- **Systemic and just transformations**
- **Knowledge for impact**

Evidence shows that, if left unaddressed, accelerated environmental degradation will increase social and environmental inequalities, constrain Europe's economic performance and weaken resilience. The final section of the opinion on "knowledge for impact" aims to address one of the major tensions facing evidence-based policymaking and the link between science and democracies today: Despite the evidence on risks, tipping points and cascading impacts, we are operating beyond the planet's safe biophysical boundaries.

1. Health, pollution, biodiversity and climate change

The triple planetary crisis of climate change, biodiversity loss and pollution are interconnected and mutually reinforcing crises, representing major threats to terrestrial, ocean and atmospheric health, to economies and social systems. **To safeguard Europe's long-term competitiveness and resilience, knowledge and research on the interconnections between biodiversity, climate change and pollution is essential.** Solutions and their impacts are also often interconnected, and attention to solutions that reinforce each other is important.

Healthy and functional ecosystems are fundamental to life on earth. They underpin food and water security and provide medicine and raw materials. They regulate the climate and protect against natural hazards and climate change. Without functioning ecosystems, societies face growing disruptions, increasing costs and vulnerabilities. The EU's efforts to restore nature through the Nature Restoration Regulation will, over time, strengthen resilience of natural systems and enable both adaptation to and mitigation of climate change. Nevertheless, biodiversity in Europe, and globally, is still in decline. **To halt this loss and support the effort to restore critical European terrestrial and marine ecosystems, research should focus on how nature conservation and restoration benefit biodiversity, climate resilience, and human well-being.** This includes research on the design, implementation, and evaluation of nature-based solutions to understand what works and under which conditions, and how such efforts can be evaluated and compared. Scientific **research should highlight benefits beyond ecology and consider needs across several dimensions.** For example, when developing nature-based solutions that also help secure critical infrastructure, innovations might be needed across technology (e.g. materials), finance (e.g. insurance and risk-sharing models) and governance (e.g. integrating natural assets in planning processes and accounting). At the same time, limits to nature restoration – both in terms of how much ecosystems can recover and how fast restoration

benefits will appear – must be acknowledged. Ongoing pressures on European habitats must be reduced. If not, continued pressures from intensive agriculture, land-use change, pollution, overexploitation of resources, invasive exotic species, and climate change will far outweigh potential restoration efforts. **Research should be directed at reconciling thresholds and irreversibility of ecosystem degradation to ensure policies are realistic and effective.**

Despite important progress in mitigating climate change, Europe is warming twice as fast as the global average. Extreme weather events driven by climate change are impacting people's lives across the entire continent. Downpours are increasing in severity, while Southern Europe is plagued by water scarcity, extreme heat and wildfires during summer and downpours in winter. At the same time, the EU's carbon sink related to land use, land use change and forestry has been unexpectedly reduced over the last decade. If the carbon sink does not recover, it affects, negatively the prospects of reaching net emission reduction goals. This threatens security, public health, ecosystems, livelihoods, infrastructure and the economy. Science on Climate Change and feedback mechanisms with ocean, freshwater terrestrial ecosystems, atmospheric science will be crucial.

Research needs to focus on how mitigation and adaptation policies feedback with biodiversity, pollution, health, as well as economic and financial systems. A key priority is to assess the design and early implementation of climate policy instruments such as carbon credits, nature credits, and the Carbon Border Adjustment Mechanism. **Research should evaluate whether these tools are effective** in reducing greenhouse gas emissions, preventing carbon leakage, supporting the climate transition of EU industry, and avoiding unintended social, environmental, or economic impacts. Research should develop robust methods to evaluate the effectiveness of different climate adaptation measures, including benefits for terrestrial and marine ecosystems, pollution reduction, and health, as well as the risks of maladaptation. Additionally, research should be attentive to the increasing impact of time lags in collection and use of data and variance in methodologies between countries in, for example, GHG inventories and the LULUCF sector to ensure that carbon sink data can support climate policy more effectively. To support the European Ocean Pact, research is needed on how to enhance the competitiveness of the blue economy in the EU and support transitions in both traditional and emerging blue economy sectors.

In a letter to the European Commission informing the development of the work programmes of Horizon (2026-2027) and FP10, the EEA Scientific Committee has previously recommended the concept of One Health as one approach to support more integrated assessments, acknowledging the deeply interconnected relationship between humans, nature and the more-than human world. One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of humans, domestic and wild animals, plants, and the wider environment (incl. ecosystems). **By combining sectors and disciplines, One Health could help effectively address challenges such as infectious diseases, antimicrobial resistance, food safety, chemical pollution, and the health as well as securing the integrity of ecosystems.** Research priorities related to One Health include the need to better understand risks from plastics (including micro and nanoplastics), harmful algal blooms, antimicrobial resistance, and zoonotic diseases. Research is also needed on how climate change, biodiversity loss, and ecosystem restoration influence disease ecology, the benefits to health from the circular economy and zero-pollution, as well as pathways to more sustainable food systems.

Main recommendations for knowledge development on health, pollution, climate change and biodiversity:

- Develop knowledge to better understand the interconnections between climate change, biodiversity loss, and pollution, and to support solutions that address conflicts and synergies across the three dimensions, on land (e.g. circular economy) as well as on water (e.g. the blue economy).
- Build evidence on nature restoration and nature-based solutions, including their effectiveness, limits, as well as co-benefits for biodiversity recovery, climate adaptation and mitigation, pollution reduction, and human well-being.
- Apply One Health as one approach to highlight co-benefits and integrate dimensions, sectors and disciplines.

2. Systemic and just transformations

The EU has responded to the volatile global context through the Competitiveness Compass, a strategic policy framework to 2029 that acknowledges the interlinkages and synergies between greening industries and securing strategic autonomy over material and energy in response to geopolitical tensions. **Future research should support this integrated, systemic perspective to identify co-benefits between environmental and industrial policies.** Examples include synergistic measures like reductions in air pollution and greenhouse gas emissions that benefit human health, ecosystems and climate change, and innovations in value chain optimisation that support both climate and environment as well as competitiveness and resilience. Nevertheless, given the severe impacts on Europe from the triple planetary crisis and geopolitical instability, **focus of this research should be to support deep transformational change that strengthens competitiveness, resilience and strategic autonomy while maintaining social well-being.** Climate change and ecological degradation are already constraining European industrial activity through water scarcity and extreme events. **Research should support industries and regions in adapting to such limits to increase their resilience**, acknowledging that ecological health is a precondition for security as a whole, including long-term prosperity and well-being.

Understanding the material and ecological footprint of transitions is critical to avoid creating new vulnerabilities. Decarbonisation cannot be pursued in isolation from considering the use of materials and energy, pollution and ecological impacts. **Research should focus on system-level interactions, including how industrial transition pathways affect demand for raw materials, land and water use, climate mitigation, biodiversity, and human health, and how circularity can reduce dependencies on imports and exposure to supply-chain disruptions.** Transitions in multiple systems, such as energy, food, mobility, housing, influence each other, with the risk of unintended consequences, e.g. how transitions (e.g. electrification) can accelerate resource consumption and land use. Research and knowledge should be directed at such interconnections to support decision-makers in avoiding unintended consequences as far as possible.

Resource efficiency and circularity are main pillars of the Commission's Competitiveness Compass. However – and despite the intensified competition for resources – Europe's transition to a circular economy is slow. **Future research should focus on ecological as well as economic impacts of circular economy, including**

quantitative assessments of circular strategies and their impacts on biodiversity, climate change, pollution and health. By connecting ecological integrity with economic performance, research can identify areas where environmental sustainability and industrial competitiveness are mutually reinforcing, including efforts to bring more high-quality secondary raw materials to the European market, developing circular business models, monitoring material flows, and addressing hazardous substances in recycled materials.

Financing Europe's industrial transformation requires addressing both *transition finance* to unlock path dependencies of existing industries and *first-of-a-kind* funding for new technologies such as clean tech. Existing sectors like steel, cement, and chemicals need capital to reconfigure plants and adopt low-carbon processes, while early-stage cleantech projects struggle to scale due to high perceived risk. **Research is needed to gather evidence on how such projects are financed and where bottlenecks occur.** Closing gaps will require new financial approaches that look beyond individual assets, better integrate public and private investment, and account for the long-term strategic, environmental, and economic value of industrial transformation. Policy tools such as blended finance, public guarantees, and clear regulatory signals are key to mobilising private capital and ensuring Europe remains competitive.

As highlighted by the Commission, transitions of European industries and societies must be just and fair. While effects on employment and jobs are central, justice also includes dimensions such as fair sharing of costs and benefits (distributional justice), meaningful participation in decision-making (procedural justice), and acknowledging diverse identities, knowledge and values (recognitional justice). Successfully navigating the complexities of just transitions requires careful consideration of local realities and geographical differences. **Research on justice must include all these elements, to be applied across a broad range of sectors and regions.** Fair and inclusive transitions strengthen social cohesion, democratic legitimacy, and support for ambitious climate, biodiversity, and pollution-reduction goals. Emerging debates on multispecies justice invite a broadening of justice frameworks to consider how sustainability transitions affect other-than-human species and ecological systems, alongside human social concerns.

Digitalisation and artificial intelligence are key enablers supporting systemic and just transitions. Currently, data gaps and fragmentation hinder effective policy implementation and monitoring. Oftentimes, only a limited number of organisations have capacity and access to develop such services. In addition, there are different institutional frameworks for producing knowledge and data across systems and sectors. Key priorities include developing interoperable, FAIR, and federated data infrastructures that reduce fragmentation and lower entry barriers, enabling more actors to handle and process large, complex environmental datasets into actionable knowledge. At the same time, **research must critically assess the social and environmental impacts of digitalisation itself – such as energy use, resource demand, and employment effects – and support the development of green, inclusive, and accountable digital systems that align sustainability goals with equity and good governance.**

Main recommendations for knowledge development on systemic and just transformation:

- Include elements on justice, climate neutrality and biodiversity protection and ecological resilience in knowledge on industrial transformation, acknowledging and integrating them as preconditions for social and economic stability.
- Examine interactions between industrial and circular transitions across systems, and explore how industrial pathways, circular economy strategies and supply-chain changes affect biodiversity, climate, pollution and European strategic autonomy.
- Investigate enablers of transitions, including financing (e.g. exploring institutional capacities and barriers to funding and implementation), and digitalisation (e.g. developing accessible, interoperable digital and data systems that lower barriers to entry and enables the inclusion of complex global datasets in decision-making).

3. Knowledge for impact

While evidence is growing on the risks related to environmental degradation, evidence-informed policymaking is increasingly being challenged from growing complexity, the use of mis- and disinformation and politicisation of expertise. This presents a major challenge to European democracies. At the same time, there is a long-standing scholarship that addresses the limits to conventional scientific methods when addressing complex challenges such as climate change, biodiversity loss and pollution. While evidence is indispensable for policymaking, reductionist scientific approaches – where individual components of complex systems are isolated or organised in disciplinary silos – will fail to capture the reality of socio-ecological systems, characterised by non-linearity, long time horizons, and feedback across scales. This is perhaps most visible in the example of nature, where ecosystem functions and restoration outcomes are highly dependent on relationships between species, landscapes, human cultural practices, and historical land use. These are dimensions which are not easily reflected in standard models or indicators. Nature can also be understood and valuated in different ways, not only as a source of resources – reflected in concepts like ecosystem services – but as a living system and a source of identity and meaning. Such differences in values will shape how individuals, groups, and societies perceive risks and trade-offs, and thereby also the policies designed to navigate them.

More evidence will not resolve dilemmas and conflicts that are based on differences in values. Instead, knowledge that supports the ability to hold disagreements, work across different perspectives and remain constructive, is needed. In this context, knowledge production becomes a practice that requires humility and trust rather than merely a scientific or technical expertise. Because interventions in one area can have unintended effects in another, differences in perspectives and values are a resource rather than an obstacle when challenges are complex and interconnected. More participatory approaches are therefore needed. For example, foresight processes can help anticipate potential risks and identify opportunities. Anticipatory governance that actively identifies and prepares for future risks can build social, economic and ecological resilience across systems. Systems thinking is necessary to explore interactions between pathways in and across systems, feedback loops and interdependencies, as well as interlinkages between governance issues.

Research must go beyond traditional disciplinary boundaries towards inter- and trans-disciplinarity. Natural sciences must be integrated with social sciences and humanities, indigenous and local knowledge,

as well as stakeholder experiences. Strengthening integrative and reflexive research, scenario-based analysis and co-produced knowledge can help policymakers navigate uncertainty more transparently and improve the relevance of knowledge. Mechanisms are also needed to ensure that practical knowledge is also captured in science production, such as through citizen science, multi-stakeholder advisory committees and stakeholder engagement in policy impact assessments. Sustainability transformation is also a cultural and psychological challenge that requires transformative inner capacities. Art and the making and interpretation of experience through stories and other forms of expression have a role to play.

Recognising interconnections and complexity also require innovations to how we govern such issues. **Research is needed to increase the understanding of emerging new governance approaches, including the institutional capacities required to navigate complex transitions over time.** At the same time, policymakers lack systematic evidence on how to manage trade-offs and synergies relevant to transformation, such as interactions between decarbonisation, clean-technology deployment, land- and ocean-based carbon sinks, bioeconomy, biodiversity, and justice. The European Commission confirms the gaps in implementation across environmental areas and resulting costs to society. Improving implementation requires more effective (meta)governance through a combination of leadership, institutions, tools, training, mechanisms and engagement processes tailored to the national or subnational context. Research is needed to unite different approaches available to evaluate policy effectiveness and develop joint frameworks, and metrics.

Finally, the Committee would like to highlight how Europe's competitiveness and development are deeply interconnected with developments at the global level. Solutions and responses to planetary challenges, critical resource dependencies and development challenges need to be shared. Transitions must be economically viable, environmentally sustainable and socially grounded across all continents. Research cooperation with countries outside the EU must therefore be strategically explored and expanded. Expanded partnerships would ensure that solutions developed in Europe are effective, scalable, and responsive to the realities of an interconnected world.

Main recommendations for knowledge development to support action:

- Develop evidence that informs decision-making in contexts of high uncertainty, anticipating trade-offs and supporting constructive debates on risks and priorities.
- Support inter- and trans-disciplinarity; approaches that integrate across and go beyond conventional scientific disciplines to include local and experiential knowledge and acknowledge the diversity of values and lenses for understanding.
- Explore emerging governance approaches that consider the social, cultural, and psychological dimensions of transformation, including the role of behaviours, norms, and individual and institutional transformative capacities.

Annex: Detailed list of research and knowledge needs across areas

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1. Health, pollution, biodiversity and climate change

Recommendations for research on planetary health

Research approaches for planetary health

- Investigate tipping points to identify robust early warning indicators, model the complex dynamics leading to state shifts, and assess the potential cascading impacts on the economy and human well-being.
- Investigate the trade-offs, synergies and health co-benefits in reducing net greenhouse gas (GHG) emissions in 90% by 2040 and the zero pollution and circularity agendas.
- Investigate synergistic and cumulative effects of multiple stressors on ecosystem health on land, ocean, and resilience and human well-being, developing new experimental and modelling approaches to understand how these pressures interact.
- Quantitative assessments of the use of pesticides in agriculture and the impacts on pollinators and soil biodiversity, including economic estimates of harm.
- Investigate the value of sustainable soil use and the potential for agricultural gains. Develop new, cost-effective technologies for large-scale soil health assessment, including research into advanced remote sensing techniques, the use of environmental DNA (eDNA) for soil biodiversity analysis, and the development of low-cost, in-situ sensor networks.

Feedback effects, thresholds and systemic risks

- Prioritise research on feedback effects within and across ecological, social and technological dimensions and how these shape transition processes over time. This includes research that focuses not primarily on transitions in single systems, such as agriculture or mobility, but rather addressing the interconnections between these systems as they transition. For example, by exploring feedback between:
    - the roll out of technologies to deliver climate neutrality, zero emissions and boosting of competitiveness.
    - sustainable resource use and competitiveness across industrial sectors.
    - protected areas (land, sea), biodiversity gains and gains in living resources that provide ecosystem services, such as pollinators and fish stocks.

Monitoring biodiversity, ecosystems and planetary boundaries

- Assess the potential to apply AI and machine learning to biodiversity and pollutant monitoring, by analysing remote sensing and in-situ monitoring data. This includes developing algorithms to process satellite imagery for habitat mapping, analyse acoustic sensor data for birds and bats, and automatically identify species from camera trap footage, enabling large-scale, real-time tracking of species populations and habitat quality.

- Make use of the new generation of European ocean observation technologies and capacities to investigate the environmental impacts of maritime transport and marine pollution on marine ecosystems. Assess the cost-benefit of using underwater drones, fixed and mobile sensor networks, and advanced bio-logging technologies to provide continuous, large-scale data on the chemical, physical, and ecological resilience of Europe's seas.

Impacts of human activities on ocean ecosystems and marine resources

- Explore the impact of seabed mining on marine ecosystems, develop knowledge and data base feeding into international conventions (UNCLOS, BBNJ) the International Seabed Authority.
- Map and assess cumulative impacts of pressures from human activities and climate change on the ocean for scenarios that can guide the sustainable management of future use of the ocean with the goal of a sustainable multiuse blue economies and marine protection. Pressures include disturbances related to shipping, mariculture, offshore energy, habitat destruction and fishing, technical marine carbon dioxide removal.
- Scientific studies into local, regional and interregional impacts of marine Carbon Dioxide Removal (mCDR) measures at various spatial scales on marine ecosystems.
- Impact of marine plastics pollution (micro- nano) and associates pollutants on commercially relevant marine species
- Develop projections for seafood species and sustainable fisheries in exclusive economic zones to guide management across marine environmental policies.

Modelling, accounting and decision-support tools

- Interdisciplinary and transdisciplinary research bridging fields such as ecology, climatology, sustainability transitions, ecological economics, technology assessment and life cycle analysis.
- Research on the interplay between socio-technical and social-ecological dimensions of systemic change to deepen understanding of the role of nature and nature-centric approaches in sustainability transitions.
- Develop and operationalise a comprehensive, standardised Natural Capital Accounting framework for the EU. Identify robust and verifiable methodologies for valuing a wider range of ecosystem services, alongside investment in the monitoring infrastructure needed to track the use of ecosystems services in the European economy.
- Make best use of existing European environmental research infrastructures in FP10 projects, such as ERIC landscape.
- Earth Observation (EO) capacity and new automated tools, including both remote and in situ, are crucial for producing data on planetary boundaries, land use change, pollution (water, ocean, land air) and climate change.
- Develop integrated assessment models on land use, capable of simulating the environmental, economic, and social outcomes of different land-use scenarios, providing policymakers with tools to navigate the complex trade-offs between, for example, biofuel production and food security, or solar farm deployment and biodiversity conservation.

Recommendations for research on climate change

- Research to support the development of an improved assessment scheme for carbon credits. Assess the design and implementation of carbon credits, and evaluate their success in reaching goals, including extracting recommendations and identifying success criteria.
- Develop recommendation for measures on demand-side and how to reduce the EU's impact on GHG emission from third countries.
- Assess the early implementation of the Carbon Border Adjustment Mechanism (CBAM), carbon credits and nature credits in terms of effectiveness in protecting climate transformation of EU industry and preventing carbon leakage, in reducing GHG emissions in third countries, economic efficiency, environmental integrity and in avoiding potential unintended consequences.
- Investigate the potential for carbon removals under climate change, including through nature-based solutions (e.g., improved forest management, reforestation, afforestation, biochar, enhanced weathering) and technological approaches (e.g., BECCS, DACCS), including cost-benefit analysis, methodologies for monitoring and verification of performance.
- Develop robust methodologies to evaluate the effectiveness of different adaptation measures, including transformative adaptation and no-regret measures, aiming to build a "what works" evidence base for policymakers, allowing them to prioritise investments in adaptation solutions with multiple benefits and avoid maladaptation.
- Translate the outputs of new generations of climate and Earth System models into specific, decision-relevant risk indicators for key economic sectors (e.g., granular flood risk maps for infrastructure assets, projections of drought frequency for agricultural regions, changes to small-scale extreme weather events such as cloudbursts, lightning and hail), developing improved pathways for this information to become accessible to businesses, investors, financial institutions, insurance bodies and public authorities.
- In addition to continued addressing of the science on tipping points, investigate potential societal and political responses to climate system tipping points if they take place, i.e. what would/could be done if a certain tipping point were reached.
- Develop indicators and monitoring systems to assess "just transition" to track how costs and benefits of mitigation solutions and adaptation investments and their outcomes are distributed across different social groups, ensuring that policies do not inadvertently reinforce existing inequalities, but promote acceptability and feasibility.
- Pursue science that can support key issues in climate negotiations and other relevant international collaborations, e.g., on modalities for Loss and Damage. Ecological Loss and Damage and innovative climate finance solutions.

Recommendations for research on One Health

Health impacts from pressures and exposures

- Comprehensive assessments of impacts on health – including occupational – at the EU level, including diffuse pollution and levels of chemical pollutants in various environmental media, as well as in biological matrices (i.e. through human biomonitoring, aiming at full EU representative sample coverage).
- Quantitative evidence of harmful algal blooms, the drivers behind such blooms and impacts on seafood safety.
- Generate quantitative evidence of the impacts of plastics pollution on food safety and the implications for human health, including evidence of human exposure to microplastics through diet.

- Assess the impact of the EU zero pollution agenda on water, soil and air quality, as well as on food safety and human health.
- Strengthen research on chemical mixtures, emerging pollutants, and linkages between the health of ecosystems and human health.
- Research on the transmission of AMR genes and survival of AMR pathogens in surface waters and in soil, and its possible implications for animal and human health.
- Research on chemical pollution in waste waters and sludges produced by wastewater treatment plants.
- Support research and data integration that addresses novel entities (emerging chemicals) and their systemic impacts on planetary boundaries, with the aim of contributing to the development of planetary boundaries for pollution.

Ecosystems, food and disease

- Explore links between industrial livestock farming and the emergence and outbreaks of zoonotic diseases.
- Promote research on how disease ecology is affected by climate change and biodiversity loss, and how it may be impacted by ecosystem restoration and nature-based solutions.
- Future exposome initiatives should take into consideration environmental changes elicited by climate change and biodiversity loss in a one health perspective.
- Compare the environmental, economic, social, and health impacts of different future food system scenarios for Europe, using integrated modelling to assess various combinations of dietary change (e.g., shifts to more plant-based diets), agroecological farming practices, and technological innovation (e.g., precision agriculture, alternative proteins).

Innovation

- Research on how to increase the environmental sustainability of the health sector and health systems, specifically the reduction of its carbon intensity[1] through green procurement, as well as strategic changes in care pathways.
- Possible health benefits of transitioning to a circular economy, including but not limited to reducing environmental damage.
- Support research and innovation in plant-based proteins, fermentation-based technologies, and cultivated meat and fish, which have the potential to drastically reduce the land, water, and environmental footprint of the food system.
- Develop and demonstrate advanced, energy-efficient, and cost-effective technologies for removing persistent chemicals, pharmaceuticals, and microplastics from wastewater. This should include a portfolio of approaches, from advanced oxidation processes and novel membrane filtration systems to innovative nature-based solutions.
- Further develop chemicals and materials that are safe and sustainable-by-design through the practical application of existing guidelines. This should include a focus on developing high-

[1] See Pichler 2019, International comparison of health care carbon footprints and Rizan et al. 2024, Purpose and limitations of carbon footprinting for healthcare

performance, PFAS-free coatings and materials, non-toxic flame retardants, and safer alternatives to bisphenols in plastics and resins.

Monitoring, early warning and prevention

- Research using integrated monitoring, such as exposome approaches, and digital tools such as big data and AI.
- Further develop early warning systems for the pollution and degradation of ecosystems. This includes the development of "smart" pollution monitoring systems using networks of IoT sensors to collect data on air and water quality and employ AI algorithms to analyse this data in real- time, identifying pollution sources and automatically alerting enforcement agencies to breaches.
- Support tools and methodologies for identification of emerging chemical risks and for assessment and prioritization of early warning signals.
- Support the ability of cities to design effective noise reduction plans and protect public health through the development and deployment of low-cost, wide-area noise sensor networks. Explore options to combine with citizen science initiatives using smartphone apps to create detailed, dynamic noise maps for European urban areas, providing a much richer evidence base for urban planning and traffic management.

Policy, regulation and prevention

- Developing health economics to assess the costs of inaction and the return on investment of upstream interventions to prevent disease and death.
- Develop advanced tools to identify co-benefits for environment, climate and health, such as the health and climate gains of reduced chemical emissions and exposure, to enable better joined-up policy responses.
- Support tools and methodologies for translating monitoring and HBM data into actionable regulatory insights across agencies (e.g. EFSA, ECHA), ensuring scientific results inform chemical-related regulations (e.g. REACH, CLP, WFD, OSOA) and environmental health policies.
- Foster mechanisms for timely uptake of scientific data into EU risk assessment procedures, including improved evidence appraisal and communication to policymakers.

In addition to these recommendations, the Scientific Committee also wishes to flag knowledge needs identified by ongoing work in the environment-health nexus:

- The EU-funded HERA project identified five priority research areas for the future European research agenda in the environment, climate and health nexus, including the triple planetary crisis of climate change, biodiversity loss and environmental pollution; transport, mobility, sustainable solutions and health; energy transition and health; waste and the circular economy and health; and ethics and philosophy and health.
- Research on the exposome - all the physical, chemical, biological and psychosocial factors, and their interactions, which have an impact on biology and health – has generated research recommendations, namely: impact of global change; impact of current transitions; relevance to public health; relevance to medicine; new tools and methodologies.

Recommendations for research on nature-based solutions

- Promote research on the design, implementation, and evaluation of nature-positive innovations that both reduce negative environmental impacts and generate positive outcomes for biodiversity, ecosystems, climate mitigation and adaptation, human activities and overall environmental health.
- Assess the design, implementation of nature credits, and evaluate their success in reaching goals, including extracting recommendations and identifying success criteria.
- Undertake quantitative cost-benefit analyses of nature-based solutions.
- Assess the application and value of nature-based solutions for adapting to climate change, as well as contributing to mitigation through carbon sequestration.
- Assess the role and value of healthy ecosystems in providing security functions—such as natural flood protection, mitigation of heatwaves, and prevention of wildfires.
- Explore the potential to scale up nature-based solutions as a form of critical infrastructure in efforts to adapt to and mitigate climate change, encompass technical innovation (e.g., advanced materials science for green roofs and permeable surfaces), financial innovation (e.g., new insurance models that value the risk-reduction services of restored wetlands), and governance innovation (e.g., methodologies for integrating natural assets into national security and infrastructure planning).
- Assess the role of nature-based solutions in reaching good ecological and chemical status of surface and ground waters, as well the marine environment.
- Build knowledge on climate change impacts on biodiversity, water quality and quantity, and other ecosystem services through quantitative analysis of aquatic ecosystems and explore how such risks might be mitigated through catchment scale or river basin management.
- Support a diverse portfolio of projects to scale up ecosystem restoration, ranging from technical innovations, such as drone-based seed dispersal for reforestation and 3D-printed structures for marine habitat reconstruction, to large-scale peatland rewetting and river restoration.

Recommendations for research on just transitions

Broadening scope of just transitions

- Broaden the scope of research on just transitions beyond energy transitions to include agriculture, forestry, housing, transport, food systems, adaptation to climate change, circular economy and digital inequalities.
- Explore the potential of multispecies justice as an emerging research perspective to complement established approaches to environmental justice, by examining how sustainability transitions affect other-than-human species and ecosystems alongside human communities
- Investigate sector specific transformation gaps and monitor the development of sectoral transition pathways and their social implications.
- Fund longitudinal, community-based studies on justice-related emotions and how they interact with distributive, procedural, and recognition dimensions.

Social experiences, inclusion and recognition

- Expand research on children and youth by examining how governance inclusion shapes justice outcomes and how inequalities affect experiences of transition.
- Critically examine circular economy policies to ensure they address labour rights, informal work, gender equality, and global justice.

- Advance research on the implications of the green transition for inclusive and quality job creation, by complementing data analysis with a case study approach. Prioritize research that evaluates not only the number of jobs created, but also their quality, stability, and distribution across regions and groups.

Labour, livelihoods and the green transition

- Strengthening knowledge and collecting empirical evidence on the impact of climate risks on jobs and workers in Europe across a range of sectors, including agriculture, transport, construction and tourism.
- Strengthen our understanding on participation and inclusion mechanisms, and their effectiveness in achieving socially accepted transitions. Capacity building and participation are integral to just transitions. Develop standardized tools to distinguish tokenistic from empowered participation and address local-level capacity gaps.
- Advance intersectional approaches that capture how class, gender, migration, and disability shape vulnerabilities. Shift from diagnosing barriers to systematically studying real-world just transition policy implementations, evaluating their distributive, procedural, recognition, and intergenerational justice outcomes, and identifying best practices across these dimensions.
- Develop knowledge to enable the operationalisation of intergenerational justice, by documenting methodologies for:
    - impact assessments that do not discount the future,
    - institutional mechanisms that safeguard future generations against biodiversity loss, chemical legacies, and long-term unfairness,
    - effective indicator-based monitoring.

Monitoring and indicators

- Research to develop scenario-based data-driven simulations to monitor distributional impacts of climate and environmental policies, e.g. changes in energy poverty rates, impacts on affordability for different socio-economic groups across geographic regions over time.
- Research to strengthen understanding of unequal regional and local impacts of transition, territorial disparities, and interplay between geographical scales.
- Research on household and income group vulnerabilities and how these affect affordability of clean products and clean energy solutions.
- Research on policy and market mechanisms to ensure that sustainable goods and services are cheap and accessible to all.
- Research related to justice as a potential barrier to transition processes.

Recommendations for research on digitalization and data infrastructure

- Promotion of open science practices and advancing interoperable and federated data spaces/lakes for all-round environmental data as well as leveraging the EOSC ecosystems and open-source tools/communities while improving capacity building to make open science a new normal across diverse domains. To enable scalability, representative and strategic demonstrators across the EU missions should be targeted to serve as catalyst for the scientific community and broader stakeholders for transforming data into solutions and evidence-based decision-making capitalising the currently running projects under EOSC and research infrastructures. Embracing AI-based methodologies e.g., large language/foundation models should be considered.

- Promote research on the role of AI and digitalization in sustainability transitions and their environmental impact on optimising and/or transforming current systems of production and consumption.
- Develop and pilot digital tools designed to streamline the implementation of green policies, including AI-powered platforms to accelerate permitting for renewable energy projects, automated systems to help businesses with sustainability reporting requirements, and integrated digital platforms to improve coordination between different levels of government and regulatory agencies.
- Expand Earth observation-based products beyond the conventional ones, for example, to provide more spatio-temporally accurate insights on environmental dynamics e.g., land use change, pollution (inland water, ocean, land, air) and climate-driven changes, land degradation. Doing so will require including spatial analysis techniques and geoinformatics techniques.
- Explore the potential of developing large foundation models building on the Copernicus data space and EEA's data hub to enable autonomous detection of environmental changes e.g., deforestation, urbanization, climate-born impacts with a higher spatial and temporal resolution. Such foundation models in nature will result in providing novel indicators for monitoring and analysing environmental (terrestrial and marine ecosystem) changes. Doing so should/will support enforcement and move enforcement from a reactive, inspection-based model to a proactive data-driven one. For example:
  - analyse historical satellite imagery from the Copernicus programme and other global ones to detect illegal deforestation in near real-time, in support of the Deforestation-free Products Regulation,
  - coupling EO data with citizen observatories and networks of IoT sensors in rivers and industrial sites to continuously monitor for pollution breaches.
- Enhance nutrient monitoring in water bodies through the development of harmonised, farm-level data collection systems for pesticide and fertiliser use, potentially leveraging digital farm management tools.
- Stimulate investments in interoperable, transnational research infrastructures and AI-enhanced Earth observation systems to support resilience and foresight studies through the use of cross-sectoral tools. Examples include integrated Earth system models, digital twins, high-resolution scenario tools, scenario-based planning, resilience metrics across sectors, cross-sectoral resilience research, vulnerability mapping and adaptive governance.
- Develop large-scale "digital twins" of Earth's systems: high-resolution models, powered by AI and fed with real-time data from sources like the Copernicus satellite programme. The aim is to simulate the complex interactions between environmental and societal systems, allowing for better foresight, risk assessment, and the stress-testing of policies. Leverage environmental data from existing initiatives like DestinE.
- Research on the potential negative impacts of digitalization and AI, including job losses and the environmental footprint in terms of energy demand and water use for cooling. Explore options for the development of energy-efficient data centres and cooling systems, research into low-power computing architectures and "Green AI" algorithms, and the promotion of circular design principles for electronic hardware to facilitate repair, reuse, and high-value recycling. This includes research into the ecological impacts of digital infrastructure and support the development of innovative solutions and best-practice guidelines for siting, designing, and operating this infrastructure in a way that minimises harm to biodiversity and ecosystems.

2. Systemic and just transformations

Recommendations for research on the circular economy, sustainable resource use and strategic autonomy

- Promote research on how to boost the market for high-quality secondary raw materials, including though:
    - the use of standards and certification,
    - the improvement of scrap classification and traceability in the value chains.
    - The development of innovative high-quality recovery processes.
    - the development of relevant logistics and stock management,
    - capacity building tailored to specific sectors,
    - further enhancing product design and durability, reuse and repair, refurbish models,
    - better metrics to assess material footprint, circularity and monitoring of life cycles.
    - scaling up investments, mobilizing private capital, making use of public procurement, and investing state aid.
- Investigate the economics of the circular economy, including financing of the circular economy transition, possible rebound effects related to circular economy policies, price signals in secondary raw materials markets and for circular business models, quantity and quality of employment in the circular economy.
- Investigate new sources of critical raw materials to ensure their availability in EU, given the current geopolitical situation and the associated risks of supply chain disruptions, including through the development and maintenance of adaptable database of materials stocks and flows.
- Investigate how to better integrate justice, equity and inclusion in circular economy transitions. This includes research on the effectiveness, efficiency and justice aspects of circular economy and resource use policies (such as policies on extended producer responsibility, recycled content targets, eco-design, right-to-repair, digital product passports, circular procurement) both on EU and national levels.
- Research on actual market penetration and trends in circular business models such as sharing models, product-service-systems, remanufacturing, repair, product lifetimes – areas where regular statistics usually does not deliver data.
- Quantitative assessment of the environmental impacts and benefits of circular economy on biodiversity, land, water, climate mitigation and pollution.
- Address the following knowledge and data gaps:
    - Generate outlook information on circular economy, including both quantitative outlooks and qualitative scenarios.
    - Analysis of performance of effectiveness of novel circularity (policy) interventions.
    - Identification of additional data on economic aspects of circular economy (value added, job creation, competitiveness) where data is scarce or only available for the waste element of circular economy.
    - Research on monitoring product ownership, including circular strategies like repair, remanufacturing, reuse. Further development and modernisation of existing circular economy metrics, such as the circular materials use rate, and waste statistics.
    - Produce systematic data and research on the quality of recycling, including quality of recycled materials, substitution potentials, looping potentials, and systems optimisation.

    - Investigate the presence of persistent hazardous chemicals in recycled materials, as well as chemical build-up across product life cycles, including transfer of endocrine disruptors and PFAS through recycled consumer products (e.g. textiles, plastics, electronics).
- Research on the sustainability of resource use, including estimating sustainable resource use levels, broken down into material categories. Research on material accumulation and their links to economic and social prosperity.
- Build knowledge on the links between competitiveness of the EU economy and circularity, with a focus on access to high quality secondary raw materials and the potential to boost strategic autonomy.
- Investigate how to shift attitudes and practices amongst stakeholders and policy makers on circularity from a "waste-perspective" to a more strategic metabolism-oriented perspective, where secondary materials are perceived as future resources to boost strategic autonomy.
- Advance innovation in resource recovery by funding breakthrough technologies for "urban mining" — the recovery of valuable materials from waste streams. Develop advanced recycling processes, including chemical, bio-based, and electro-chemical methods, capable of extracting critical raw materials from complex end-of-life products like electronics, batteries, and renewable energy equipment.
- Research and innovation into the circular economy for electronics, covering the entire lifecycle, including R&I into design for disassembly and repair, the development of automated technologies for sorting and recycling e-waste to recover critical raw materials, and the piloting of innovative business models, such as "electronics-as-a-service," which incentivise producers to retain ownership and responsibility for their products at the end of life. This includes modular design for easy upgrades and repairs, software solutions that extend the useful life of older hardware.
- On plastics, explore options for scalable, low-energy mechanical, chemical and biological recycling routes that keep plastics and polymers at “high value” without large GHG emissions or toxic trade-offs. Understand environment and climate impacts of chemical recycling.
- Explore options for scalable, low energy recycling of complex streams like multi-material packaging, fibre-matrix composites and mixed textile blends. Funds work from labs to pilot demonstrations that feed industry.
- Investigate the adoption of AI in waste sorting and demand forecasting, including machine vision for automated sorting, predictive models for secondary markets, and supply/demand matching to avoid stockpiles.
- Investigate the potential for low-cost sensing/tagging (printed electronics, secure QR/RFID) to signal material composition for disassembly/recycling but also for the digital traceability of materials to keep them in circulation, enabling remanufacturing. Explore the potential for development and implementation of Digital Product Passports to act as a digital record for products, containing information on their composition, repairability, and end-of-life treatment.
- Explore how to optimize low energy techniques for products repairability, upgradability, and disassembly across electronics, textiles, and automobile sectors.
- Identify and validate new pathways of material substitution with biobased and/or recyclable alternatives in major value chains, considering the need for potential mitigating measures.
- Develop and assess LCA methods tailored to circular processes, accounting for multiple lifetimes, material cascades, reuse impacts and rebound effects, for plastics and other materials.
- Implement multi-stakeholder living labs and supply-chain demonstrations connecting producers, recyclers, retailers, and policymakers should be promoted via dedicated topics.

Recommendations for research on industrial transformation and decarbonisation

- Go beyond a narrow focus on isolated technological developments in industrial decarbonisation, to provide research that enables the maximisation of the co-benefits of decarbonisation and the reduction of environmental pressures. This includes for example research that explores the synergistic reduction in air pollution and greenhouse gas emissions.
- Promote research that defines strategic priorities and high-impact measures for industrial transformation, including regional, sectoral and technological development priorities, with a view to maximizing investment impact and co-benefits across decarbonization, depollution and circularity.
- Promote research that promotes new innovative product mixes and material efficiency in forest industries, leading to more novel and efficient bioeconomy, increased climate benefits and reduced harvesting pressure.
- Integrate wider transition and sustainability perspectives into technical research and innovation to align technology and societal goals at early stages of development.
- Investigate approaches, technologies and systemic shifts that enable the adaptation of societies in regions affected by drought and water scarcity to reduced water availability. This should include the adaptation of sectors with high water use, such as agriculture, energy generation and digital transformation.
- Explore the potential for competitive and sustainable business models in hard-to-abate industrial sectors, including steel, cement and aluminium, including through the application of green hydrogen, electrification and carbon-capture and storage.
- Assess infrastructure needs for a European hydrogen network and pathways towards development, including policies and investment options.
- Assess progress under the Net-Zero Industry Act towards enhancing the availability of CO_2 storage sites to reach an annual injection capacity of at least 50 Mt of CO2 by 2030. Track actions by oil and gas producers to help achieve this target, as legally required under the Act.
- Develop scenarios to assess the potential for carbon capture and storage to contribute to EU mitigation targets, including cost-benefit analysis and novel recommendations for how to fund investments in storage capacities, including through legal obligations for fossil fuel companies to capture emissions associated with their activities and energy products.
- Develop options for next-generation energy storage to manage seasonal variations in renewable energy supply, through a portfolio of long-duration storage technologies, such as flow batteries, green hydrogen, compressed air energy storage, and thermal storage.
- Innovation for AI-powered smart grids, digital platforms for demand-side management, and vehicle-to-grid (V2G) technologies; are essential for enhancing grid flexibility, optimising energy use, and integrating small-scale energy assets (like EVs and rooftop solar) into a stable and efficient system.
- Research into advanced grid modelling, control theory, and market design for highly decentralised power systems. This includes studying the potential for cascading failures and developing new operational strategies to ensure resilience.
- Explore the potential to cut energy demand through demand-response technologies and business models. This includes smart appliance controls, AI-powered home energy management systems, and aggregation platforms that can bundle small-scale flexibility from households and businesses into a significant grid resource.
- Demonstration projects for various fuel pathways, including advanced biofuels, synthetic e-fuels (produced from renewable hydrogen and captured CO2), and potentially hydrogen or ammonia for shipping.

3. Knowledge for impact

Recommendations on producing knowledge for action

Knowledge production

- Promote research on how knowledge is produced, understood, and made available, including perspectives from social sciences and humanities with a view to expanding knowledge to include other ways of knowing to account for the emotional, social and political character of transitions.
- Consider practical challenges and opportunities in EU-funded research projects around dissemination and uptake of research results, access and pay-walls.
- Acknowledge the value of high-quality "grey literature" (such as reports by EEA, JRC, OECD, national environmental agencies) for EU-funded research.
- Promote research grounded in the dynamics between science, policy and society. Invest in transdisciplinary research that embeds societal actors in all phases of knowledge production, use, and governance.
- Ensure the early, structured involvement of stakeholders, including scientists, policymakers, vulnerable groups and citizens, in the prioritisation of research, as well as in the active dissemination of results, e.g. create spaces for shared meaning-making such as Living Labs, exhibitions and citizen assemblies.
- Explore alternative narratives on how to achieve sustainability and test how they resonate with sample groups from across society. Test the effectiveness of environmental storytelling and science communication strategies as well as participatory experiments in influencing opinions and behaviours.
- Research on the social narrative, recognising that individuals are limited by socio-economic status and existing infrastructures.

Narratives, behaviour and societal transformation

- Test the potential for transformative educational practices for sustainable lifestyles to influence behaviours.
- Nudging more sustainable behaviour of citizens is challenging and comes with ethical considerations. Polarisation in social discourse, reduced trust in democratic institutions and mis- and disinformation make efforts to shift behaviours difficult. More research is required to understand these dynamics. Research the drivers behind behaviours, such as consumption patterns, diet, mobility and explore how they are influenced by information, disinformation and misinformation.
- Explore behaviours and coping strategies in societies under pressure from multiple crises.
- Document the role that ecological and societal resilience play in delivering future security for Europe, with a focus on social cohesion, water and food security, access to ecosystems services and financial stability.
- Research into the drivers of and barriers to sustainable consumption, the role of social norms and values, and the effectiveness of different policy instruments (e.g., information campaigns, fiscal incentives, regulations) in promoting lifestyle changes. Develop upstream, systemic solutions that

address the drivers of overconsumption, supporting social and business model innovations that promote sufficiency and less material-intensive lifestyles, and developing policies that create a level playing field for circular business models like repair, reuse, and remanufacturing.
- Investigate the drivers of car dependency and the most effective policy levers to promote a modal shift towards public transport, and active mobility such as walking and cycling. This includes research on urban planning, transport pricing, and the cultural factors that shape mobility choices.

Systemic transitions

- Model cascading pathways from specific environmental stressors—such as regional water scarcity, persistent crop failures, or the collapse of coastal ecosystems—to tangible security threats. This requires a novel integration of advanced climate science, hydrological and agricultural modelling, political science conflict analysis, and macroeconomic modelling to provide policymakers with robust, forward-looking risk assessments.
- Build knowledge on how transitions in multiple systems, such as energy, food, mobility, housing, influence each other and may have positive or negative implications for pollution, climate change and biodiversity loss. In particular, explore how some sustainability transitions (e.g. electrification) accelerate resource consumption and land use.
- Integrate nature in socio-technical approaches to analysing radical change, allowing better understanding of the material impact of transitions, including their ecological outcomes.
- Research to develop robust and standardised methodologies for whole-life carbon assessment of buildings, and to investigate low-carbon alternative materials and construction techniques.
- Document development, piloting, and scaling of innovative business models that are inherently sustainable, including models based on circular economy (e.g. product-as-a-service, remanufacturing), sharing economy, and business models aimed to regenerate natural capital.

Systemic risks

- Undertake systemic risks assessments that map risks and responses, and document shocks and impacts on critical societal functions.
- Address knowledge gaps regarding cascading risks across systems. This includes investigating the impacts of climate change on waste management, whereby climate-related disasters may generate large amounts of waste or destabilise landfills; as well as the material inputs demanded by future climate adaptation measures.

Recommendations for research on innovative governance and policy effectiveness

- Research on how to tailor governance models so that they enable long-term, adaptive, and cross-sectoral policymaking and implementation in different settings.
- Investigation of real-world application of new governance models, e.g. transition governance, policy learning systems, the meta-governance of governance styles, and crisis-as-opportunity frameworks.
- Research on the types of capacities needed within public sector organisations to effectively manage sustainability transitions and how these capacities are built and accumulate over time.
- Systematic assessments of potential synergies and trade-offs between the objective of accelerating decarbonisation through the expansion of clean tech and the roll out of renewables, carbon sequestration by LULUCF, sustainable expanding the bioeconomy and conservation and restoration goals, providing policymakers with quantitative evidence to assess synergies and trade-offs.