European Commission

STRATEGIC PLAN 2025 - 2027

Research and Innovation

Horizon Europe strategic plan (2025 – 2027)

European Commission
Directorate-General for Research and Innovation
Directorate G — Policy & Programming Centre
Unit Unit G.3 - Common strategic planning & Programming Service

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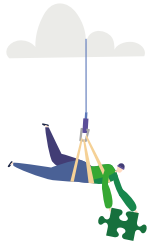
EUROPEAN COMMISSION

HORIZON EUROPE

STRATEGIC PLAN 2025 – 2027



2024 Directorate-General for Research and Innovation EN

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INTRODUCTION

The Horizon Europe strategic plan for 2025-2027 sets out the strategic orientations for the final years of the EU's largest research and innovation (R&I) programme to date – Horizon Europe.

The strategic plan aims to facilitate the implementation of Horizon Europe, serving as an interface between the overarching **EU policy priorities** and the **Horizon Europe R&I activities** set out in the Horizon Europe work programmes. It provides **planning stability** for the research community beyond the custom 2-year period of Horizon Europe work programmes. At the same time, it provides a certain degree of **flexibility** to respond to unforeseen challenges.

Through the strategic plan, investment in R&I is directed towards **tackling key global challenges** such as: climate change; pollution; the loss of biodiversity; the digital transition; an ageing population; and building a more resilient, competitive, democratic and inclusive Europe.

The analytical foundation of the document is set out in a comprehensive **strategic plan analysis**[1] conducted by the Commission. This analysis covers the EU's R&I landscape in a global perspective, including: (i) current and future global challenges; (ii) new research needs and opportunities; and (iii) how Horizon Europe could potentially address these new research needs and opportunities. The analysis also includes a large public consultation[2] with respondents representing a broad range of stakeholders. The analysis confirmed the need for Horizon Europe to continue focusing on the current EU priorities in the 2025-2027 period: in particular: **(i) the green transition; (ii) the digital transition; and (iii) building a more resilient, competitive, inclusive and democratic Europe**.

To ensure a sound foundation for investment in R&I, the Commission drafted the strategic plan using a **co-design approach** engaging a broad number of stakeholders. These stakeholders worked together to set common priorities to strengthen Europe's knowledge base through frontier research, breakthrough innovation, and the development and implementation of innovative solutions to achieve Europe's priorities. To fully harness their expertise, stakeholders will also be **involved in the preparation of Horizon Europe work programmes**[3] .

The strategic plan is also a **communication tool** reaching beyond the research community. It provides an overview of the main EU priorities for R&I, and invites a broad audience involved in – or interested in – the European R&I agenda to identify funding opportunities: from policy makers and private investors to potential applicants and the general public.

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1. European Commission, Directorate-General for Research and Innovation, Horizon Europe strategic plan 2025-2027 analysis, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/637816.
2. European Commission, Directorate-General for Research and Innovation, Synopsis report – Looking into the R&I future priorities 2025-2027, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/93927.
3. For the preparation of the 2025 work programme, the Commission will pilot an opportunity for stakeholders to give early feedback on the programme.

Stakeholders in Member States and Associated Countries can use this strategic plan as guidance to: **(i) align their research strategies with the EU priorities; and (ii) exploit synergies** with other EU programmes and with national research activities and schemes. This will improve the effectiveness and efficiency of the global R&I funding system and help to make the most of private and public investment.

EXECUTIVE SUMMARY

Since its start in 2021, Horizon Europe has been generating excellence through breakthrough knowledge and investment in **solutions to long-term global challenges**, such as climate change, biodiversity loss, pollution, the digital transformation, health threats and an ageing population.

These challenges not only remain highly relevant in the second half of the Horizon Europe programme period – they have also been exacerbated by an **unstable geopolitical context**. Russia's war of aggression against Ukraine and the Middle East crisis are examples of geopolitical situations that pose new security, democracy and supply-chain challenges worldwide. This has also put the ambition of the EU's green and digital transitions under pressure. At the same time, the pace of climate change is accelerating. Europe is by now the fastest-warming continent of the world[4] , which has extensive socio-economic, environmental and health consequences. In the future, the developments in digital technologies, including Artificial Intelligence (AI), will define the world we live in. For these reasons, it is becoming even more urgent to take transformation measures towards supporting the objectives of the European Green Deal, the digital transition and boosting our industrial competitiveness.

As laid down in the legal base[5] , the strategic plan is designed to facilitate the implementation of the specific programme of Horizon Europe, promoting consistency between the work programmes, EU priorities, and national priorities. The strategic plan acts as a compass to help policymakers: (i) stay on course with the green and digital transitions; and (ii) respond to new challenges. The strategic plan also identifies current gaps in R&I funding and takes into account the lessons learnt from Horizon 2020 and since the launch of Horizon Europe.

4. Copernicus Climate Change Service (C3S), 2023: European State of the Climate 2022, Full report: climate.copernicus.eu/ESOTC/2022.
5. Council Decision (EU) 2021/764 of 10 May 2021 establishing the specific programme implementing Horizon Europe – the Framework Programme for Research and Innovation, and repealing Decision 2013/743/EU (Text with EEA relevance).

Figure 1 – Implementing Horizon Europe

The strategic plan:

- provides **three key strategic orientations** for Horizon Europe R&I activities in 2025-2027;
- describes **32 expected impacts** of Horizon Europe R&I activities in 2025-2027;
- identifies the New European Bauhaus Facility
- identifies nine **new co-programmed and co-funded European Partnerships**;
- identifies the **EU Missions**; and gives an overview on the achievements of the first years;
- outlines Horizon Europe's approach to **international cooperation**, highlighting the importance of openness while ensuring **research security**; and
- provides direction on **specific, cross-cutting issues** such as key technologies like artificial intelligence (AI), the **balance of R&I**, the integration of **social sciences and humanities**, and the **dissemination and exploitation** of results. A dedicated section on synergies provides guidance on how to foster **synergies** with other EU and national funding programmes.

The below **key strategic orientations** outline the main priorities for 2025-2027.

- **The green transition**: Horizon Europe R&I activities must support Europe to become the world's first climate-neutral continent by 2050 and to tackle biodiversity loss and pollution. At least 35% of Horizon Europe's resources are committed to be spent on climate action and 10% for 2025-2027 on biodiversity action.
- **The digital transition**: Research to support the digital transition is key to Europe's competitiveness and open strategic autonomy[6] , and to setting human-centred standards. It is also key to achieving the green transition. In 2021-2027, it is agreed to invest at least EUR 13 billion from Horizon Europe in core digital technologies.
- **A more resilient, competitive, inclusive and democratic Europe**: Europe's social rights and democratic values and principles need a strong foundation so they can be promoted globally. Horizon Europe research activities will help provide this foundation. This includes research on civil security, on a fair and environmentally friendly economic model, on health and wellbeing and on democratic participation.

Open strategic autonomy and securing **Europe's leading role in developing and deploying critical technologies** are overarching principles that apply across all three key strategic orientations.

Horizon Europe offers a wide range of instruments for research-based solutions: from fundamental research through to breakthrough innovation and on to the development and implementation of innovative solutions.

The key strategic orientations are the guiding principles for all parts of **Horizon Europe and will be implemented through the work programmes 2025-2027**. The section 'How will the pillars of Horizon Europe help deliver on the key strategic orientations?' section provides more detailed information about the role of **Pillars I, II, III and the 'Widening Participation and Strengthening the ERA part'** to the key strategic orientations.

Horizon Europe has an explicit and **ambitious commitment** to spend at least **35% of its funding resources on climate action**. To further step-up action for biodiversity, Horizon Europe also commits to increasing investment in **biodiversity to 10%** of the Horizon Europe budget for 2025-2027. In addition, the framework programme includes a target to spend at least EUR 13 billion on **core digital technologies** during 2021-2027.

The strategic plan aims to coordinate work in the EU and beyond in order to both increase the impact of investment in R&I and boost **Europe's leadership in science and innovation**. In addition, **international cooperation** will remain the bedrock of the EU's endeavours to: (i) lead the green and digital transitions; (ii) address global health and environmental challenges at the right level; (iii) make Europe more resilient and stronger in the world; and (iv) promote **open strategic autonomy**. At the same time, measures to safeguard the EU's strategic

6. Open strategic autonomy' refers to the term 'strategic autonomy, while preserving an open economy', as reflected in the Conclusions of the European Council of 1/2 October 2020. It is further set out in the Communication from the Commission Trade Policy Review – An Open, Sustainable and Assertive Trade Policy, COM(2021) 66

assets, interests or security should be put in place where necessary to mitigate risks related to research security.

Helping to deliver a better future requires the integration of technological, cultural and **social innovation** into a comprehensive transformation of socio-economic systems. It is essential to continue **acting collectively and inclusively** at all levels; from local, regional and national to global. Acting in this way will be necessary to create, trigger and support systemic changes needed in a new geopolitical setting and deliver on the UN's Sustainable Development Goals[7]. This strategic plan also puts greater emphasis on the interaction of Horizon Europe with other EU funding programmes and regulatory frameworks, promoting **synergies** across funding schemes to maximise scientific, economic and societal impact.

The strategic plan also helps to strengthen the **European Research Area** (ERA)[8] and the implementation of the **New European Innovation Agenda**[9], aligning policy initiatives at all levels to ensure the successful implementation of European R&I priorities.

7. See the dedicated web page on Sustainable Development Goals.
8. See the dedicated web page on the European Research Area
9. See the dedicated web page on the New European Innovation Agenda

Green Transition | Digital Transition | A more Resilient, Competitive, Inclusive, & Democratic Europe

CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 5	CLUSTER 6
Health	Culture, Creativity & Inclusive Society	Civil Security for Society	Digital, Industry & Space	Climate, Energy & Mobility	Food, Bioeconomy, Natural Resources, Agriculture & Environment
1. Staying healthy in a rapidly changing society	7. Reinvigorating democratic governance	11. Reducing losses from natural, accidental and human-made disasters	15. Achieving global leadership in climate-neutral, circular and digitised industrial and digital value chains	21. Advancing science for a fair transition to a climate-neutral and resilient society	27. Fostering mitigation of and adaptation to climate change in areas and sectors covered by Cluster 6
2. Living and working in a health-promoting environment	8. Realising the full potential of cultural heritage, arts, and cultural and creative sectors	12. Facilitating legitimate movement of passengers and goods into the EU, while preventing illicit acts	16. Achieving technological leadership for Europe's open strategic autonomy in raw materials, chemicals and innovative materials	22. Facilitating the clean and sustainable transition of the energy and transport sectors towards climate neutrality through cross-cutting solutions	28. Putting biodiversity on a path to recovery, and protecting and restoring ecosystems and their services
3. Tackling diseases and reducing disease burden	9. Strengthening social and economic resilience and sustainability	13. Tackling crime and terrorism more effectively and increasing the resilience of infrastructures	17. Developing an agile and secure single market and infrastructure for data-services and trustworthy artificial intelligence services	23. Ensuring more efficient, sustainable, secure, and competitive renewable and decarbonised energy supply	29. Achieving healthy soils and forests, as well as clean air, fresh and marine water, whilst ensuring water resilience and the transition to a clean, competitive and circular economy and sustainable bioeconomy
4. Ensuring equal access to innovative, sustainable, and high-quality healthcare	10. Boosting inclusive growth and reducing vulnerabilities effectively	14. Increasing cybersecurity and making the online environment more secure	18. Achieving open strategic autonomy in digital and emerging enabling technologies	24. Using energy in buildings and industry in an efficient, affordable and sustainable way	30. Ensuring healthy food and nutrition security by making agriculture, fisheries, aquaculture and food systems sustainable, resilient, inclusive and within planetary boundaries
5. Developing and using new tools, technologies and digital solutions for a healthy society			19. Achieving open strategic autonomy in global space-based infrastructures, services, applications, and data	25. Achieving sustainable, inclusive, and competitive transport modes	31. Sustainably developing rural, urban and coastal areas
6. Maintaining an innovative, sustainable, and competitive EU health industry			20. Digital and industrial technologies driving human-centric innovation	26. Developing multimodal systems and services for climate-neutral, smart, inclusive, and safe mobility	32. Developing innovative governance models and tools enabling sustainability and resilience

Figure 2 – Overview of Expected Impacts

HOW WAS THE SECOND STRATEGIC PLAN DEVELOPED?

The Horizon Europe strategic plan serves as an interface between the EU's main policy priorities and the Horizon Europe research activities. It strives to ensure the best value and impact for Member States and Associated Countries' investment in R&I. It supports the below aspects:

- **Continuity and reliability for the R&I communities** – it sets R&I priorities beyond the custom 2-year period of Horizon Europe work programmes.
- **Communication** – it enables Member States, Associated Countries, stakeholders and the general public to engage with the European Commission on future research priorities in a transparent way.
- **Synergies with national R&I activities** – it allows Member States and Associated Countries to seek a better alignment of their national and regional R&I strategies and activities with EU priorities, by improving coordination and increasing synergies between national and EU funding.
- **Synergies with other EU funding instruments** – it highlights further opportunities for synergies with other EU funding programmes.

In preparing the strategic plan for 2025-2027, the Commission carried out a thorough and comprehensive **strategic plan analysis**[10] covering:

- global challenges and recent policies to address them;
- future challenges and disruptions and other outcomes of foresight activities
- the EU's R&I landscape in a global perspective;
- possible new research needs and opportunities arising from global challenges; and
- the potential of Horizon Europe to address important issues.

For more than a year, the Commission also engaged in an extensive dialogue with the general public, stakeholders, Member States, Associated Countries and the European Parliament on R&I priorities for the second strategic plan. The Commission organised a citizen engagement workshop[11] on 1 December 2022 to obtain the general public's view on the strategic plan. The Commission also launched a large public consultation[12] from 1 December 2022 to 23 February 2023 with 2 258 respondents representing academic or research institutions, companies and business organisations, individuals, public authorities and other stakeholders.

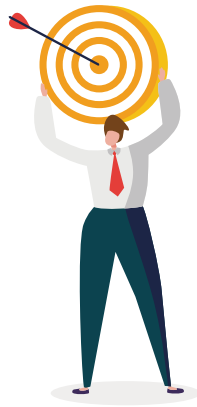
One of the main conclusions from these processes was that the need for Horizon Europe to continue focusing on the current EU priorities in the 2025-2027 period: in particular, **the green transition, the digital transition** and achieving a more **resilient, competitive, inclusive and democratic Europe**.

10. European Commission, Directorate-General for Research and Innovation, Horizon Europe strategic plan 2025-2027 analysis, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/637816.
11. Executive summary – Citizens' engagement event.
12. Looking into the R&I future priorities 2025-2027 – results of the public consultation on the past, present and future of the European Research & Innovation Framework programmes 2014-2027.

Building on the analytical phase, the second strategic plan shows continuity with the first strategic plan (2021-2024). This includes the 'impact logic', which sets out key strategic orientations and expected impacts, and describes the path from EU priorities to specific research activities in the Horizon Europe work programme parts. A staff working document[13] on the '**Evidence framework on monitoring and evaluation of Horizon Europe**' describes the intervention logic of Horizon Europe and explains the evidence that will be used for designing, informing, and improving the programme, including a comprehensive set of data and indicators. It was set up in line with the monitoring and evaluation provisions of the Horizon Europe Regulation[14].

Article 6 of the Council Decision establishing the Specific Programme implementing Horizon Europe[15] sets out in detail the elements to be covered in the strategic plan and also sets out the process for its preparation.

WHAT IS NEW IN THE SECOND STRATEGIC PLAN?



While focusing on continuity, targeted changes and novelties have been introduced where appropriate, to reflect developing societal and political circumstances.

In addition, Member States, Associated Countries, R&I stakeholders and the general public asked to make the strategic plan easier to read. In response, the Commission has:

- simplified the impact logic by removing the 'impact areas' to reduce complexity and focus on the expected impacts;
- turned the four key strategic orientations of the strategic plan 2021-2024 into three overarching, interlinked and less prescriptive key strategic orientations that encapsulate the main EU policy priorities, all of which require a significant contribution from R&I:
  - green transition;
  - digital transition; and
  - a more resilient, competitive, inclusive, and democratic Europe;
- transformed 'open strategic autonomy' and 'securing Europe's leading role in developing and deploying critical technologies' (in particular those identified in the list of critical technologies proposed by the Commission in the context of the European Economic Security Strategy) into overarching principles that apply across all three key strategic orientations;

13. Commission staff working document Evidence Framework on monitoring and evaluation of Horizon Europe, SWD(2023) 132 , 27.4.2023
14. Regulation (EU) 2021/695 of the European Parliament and 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.
15. Council Decision (EU) 2021/764 of 10 May 2021 establishing the Specific Programme implementing Horizon Europe – the Framework Programme for Research and Innovation, and repealing Decision 2013/743/EU.

- strengthened the strategic plan's coverage of **Pillar I ('Excellent Science'), Pillar III ('Innovative Europe')** and the '**Widening Participation and Strengthening the ERA**' part, to ensure better consistency between all parts of Horizon Europe, while respecting their specific objectives;
- added **new sections on specific issues**, in particular synergies, balance between R&I and social innovation;
- addressed the **latest developments** since the first strategic plan, particularly the new geopolitical situation and security concerns;
- added a new section on research security to highlight the existing tools within Horizon Europe to mitigate risks related to research security;
- identified the New European Bauhaus as a cross-cluster issue and its components for 2025-2027;
- identified nine **new European Partnerships**; and
- taken stock of the implementation of the five **EU Missions** and outlined the next steps to deploy these missions and ensure they are impactful.

KEY STRATEGIC ORIENTATIONS FOR RESEARCH AND INNOVATION

Research and innovation is at the forefront of the EU's preparedness, resilience, security and crisis response, as R&I activities have a specific capacity to offer (new) sustainable solutions to many societal, economic, environmental and political challenges[16]. Given the continued relevance of the areas covered by the previous key strategic orientations and the new developments, the following key strategic orientations for R&I are defined for 2025-2027:

- **THE GREEN TRANSITION;**
- **THE DIGITAL TRANSITION; AND**
- **A MORE RESILIENT, COMPETITIVE, INCLUSIVE, AND DEMOCRATIC EUROPE.**

These three key strategic orientations are strongly interrelated and will strengthen each other. Now more than ever, the EU must gear R&I investment towards the challenge of addressing climate change and reversing the planet's natural resources decline, while ensuring food and nutrition security. Digital technologies have a key role to play in making our economy and industry (more) resource efficient, less polluting, circular and climate neutral. Similarly, the green transition of energy, mobility and industry sectors can help counteract the growing demand for energy and natural resources and reduce the environmental footprint of the digital sector. Both the green and the digital transitions, together with the new geopolitical situation and global health threats, call for a resilient, competitive, inclusive and democratic Europe.

To achieve the EU's ambitions reflected in the new key strategic orientations, it is also essential and urgent to safeguard Europe's open strategic autonomy and to secure Europe's leading role in developing and deploying critical and emerging technologies. These are cross-cutting priorities, which are incorporated into all key strategic orientations.

Russia's war of aggression against Ukraine and the situation in the Middle East highlight the need for open strategic autonomy, impacting scientific collaboration, energy, migration, environment, food security, civil security and defence, together with the need for even faster deployment of innovative solutions, such as sustainable and low-carbon alternatives to the use of natural gas.

All six clusters under Pillar II of Horizon Europe, as well as all activities under Pillar I, Pillar III and the 'Widening Participation and Strengthening the ERA' part, will support each of the three key strategic orientations, in order to maximise integration and synergies across the respective thematic areas, and secure high and sustainable levels of impact. While some

16. European Commission, Directorate-General for Research and Innovation, Horizon Europe strategic plan 2025-2027 analysis, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/637816.

clusters are thematically more closely related to a particular key strategic orientation, they all contribute to each of them. Contributions of pillars and clusters to each of the key strategic orientations are described in the following chapter.

Key strategic orientation 1: Green transition

The European Green Deal[17] outlines an ambitious plan to address climate, energy and environmental challenges while boosting Europe's competitiveness. It aims to create a more just, inclusive and sustainable future by ensuring the security of food and of other critical resources. This includes protecting and restoring nature, reversing ecosystem degradation and biodiversity loss, and keeping human activities within the safe limits of planetary boundaries and the carrying capacity of the planet. A key goal for Europe is to become the world's first climate-neutral continent by 2050. To achieve this, the EU must shift towards a **growth model that benefits the planet** more than it harms it.

Horizon Europe will deliver on the European Green Deal. Investment under Horizon Europe will be aligned with strategic priorities helping to bring about the green transition, promoting societal changes, and prioritising circular and less polluting practices as well as systemic and behavioural changes. This will help reduce the pressure on natural resources, enabling sustainable development, generating sustainable quality jobs and ensuring economic inclusivity to leave no one behind. The green transition's success relies on creating a strong, competitive, clean and sustainable economy based on renewable energy and circularity principles, along with a skilled workforce.

Horizon Europe does not only sustain the EU's leadership in climate and biodiversity diplomacy and green innovation, but it also increases the **EU's open strategic autonomy** in the area. This path involves modernising and decarbonising Europe's industry and society, driven by leadership in net zero technologies and circular economy.

Given the urgency of the **triple planetary crisis** of climate change, biodiversity loss and pollution as well as other environmental challenges, addressing this crisis requires an unprecedented mobilisation of R&I across all sectors. This encompasses collaborative fundamental research and innovative solutions, particularly in areas like health, urban planning, construction, energy efficiency, mobility, agriculture and food systems. People should see green transition projects in their daily lives and living spaces, for example through initiatives like the New European Bauhaus[18]. EU Missions are a key tool to support the green transition.

17. European Commission, Directorate-General for Communication, European green deal – Delivering on our targets, Publications Office of the European Union, 2021, https://data.europa.eu/doi/10.2775/373022
18. For more information, see the dedicated web page on the New European Bauhaus.

The EU will need to make improvements in several areas to address ongoing and future threats. In particular, it will be necessary to improve the EU's response in two areas: (i) its **resilience** to climate-related extreme events like heatwaves, floods, droughts and wildfires; and (ii) its readiness to confront the emergence of new, climate-related, cross-border health and biological threats. Improvements in these two areas will also have the co-benefits of protecting cultural heritage and landscapes from natural and human-made risks and better addressing water resilience. These improvements will also require: (i) behavioural and structural change at societal level; (ii) transformational decision-making; and (iii) social acceptance. To prepare for these changes, it will be important to conduct research in social sciences, humanities, law, and governance. Raising awareness to social and collective responsibility and the trust in and the uptake of sustainable solutions as well as facilitating co-creation processes are part of this.

Key strategic orientation 2: Digital transition

Investment in R&I in **key digital technologies** is crucial for improving Europe's competitiveness in the digital value chain, integrating world-leading digital capabilities and technologies into its economy and industry, and strengthening its position in global markets of innovative goods and services. Such investment is also crucial to ensure that digital technologies uphold, by design, Europe's principles and values, and peoples' rights.

Artificial intelligence is transforming our society and the way we do science. It acts as a catalyst for scientific breakthroughs in a variety of scientific fields and a key instrument in the scientific progress needed for tackling the green and digital transitions. Geopolitically, leadership in AI-powered science is essential for Europe's competitive edge, prosperity, and technological sovereignty. The European AI-strategy is guided by the dual principle of **excellence** in AI and **trustworthy** AI, which, along with a thorough but innovation-friendly regulatory framework, such as the Artificial Intelligence Act[19], can harness AI's vast potential while protecting the rights and private spheres of the European people. Achieving this depends on the collective commitment of all stakeholders in the European scientific and innovation community to develop research and innovation ecosystems that are AI-ready. Encouraging people – especially underrepresented groups – to get involved is essential for advancing the development of trustworthy and bias-free Artificial Intelligence.

The EU's ability to defend and promote its economic and societal interests, as well as its credibility as a strong policy actor on the global stage, will largely be a function of its cyber resilience and digital technologies command. Therefore, it is important to identify and tackle high-risk dependencies in areas like semiconductors, photonics, digital infrastructure (high-performance computing, cloud-edge computing, communication networks), quantum technologies, cybersecurity, artificial intelligence (AI) and data, immersive technologies and emerging ones. The EU must be able to shape and orient the development of digital technologies over time according to its values and in line with its socio economic model ensuring a human-centred perspective.

19. Proposal for a regulation of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain Union legislative acts (COM(2021) 206 final, 21.4.2021)

The European way to a digitalised economy and society is about combining solidarity, prosperity and sustainability, anchored in empowerment of its people and businesses, and ensuring the security and resilience of its digital environment and supply chains. Horizon Europe plays a crucial role in shaping and developing the key technologies for the digital transformation the European way and boosting Europe's **open strategic autonomy**.

The **green and digital transitions** are intertwined and expected to mutually benefit from each other to create solutions for the future. Therefore, a successful digital transition is also key to fostering the green transition. Building on Europe's competitiveness in digital research, **cross-disciplinary research** can bring tangible benefits to the natural environment. This applies to areas like smart agriculture, fisheries control, zero pollution, net-zero and climate-resilient industry, and circular economy.

A comprehensive approach, ranging from collaborative fundamental research to innovative solutions, is crucial for advancing emerging digital technologies, identifying and fostering critical technologies and strategic sectors, assessing their impacts, and addressing weaknesses. Likewise, responsibly capitalising on the transformational potential of advanced technologies such as AI in the research process, industry and society is key to sustain Europe's competitive edge and contribute to tackling societal challenges more effectively.

Understanding the impacts of the digital transformation and carefully guiding related investment in R&I are key to safeguard the **European values**, including identifying and counteracting negative rebounds and misuse that can potentially undermine the European social and economic fabric. Anchored in the European social rights and values, the development of key digital technologies enables people and businesses to experience and use the power of digital developments in a new, human-centred, secure, and inclusive way, promoting social justice and greater economic equality.

Key strategic orientation 3: A more resilient, competitive, inclusive, and democratic Europe

Building a more resilient, competitive, inclusive and democratic Europe is a complex task that demands a comprehensive approach, inextricably linked with the EU's ambition for the green and digital transitions. R&I can help us better understand and overcome security challenges and external constraints when building up the future society as inclusive, democratic, and protective of people's health and well being.

To become more **resilient**, the EU will put more focus on preventing and responding to various threats to the EU's civil security. These range from natural and human-made disasters to violent reactions stemming from societal conflicts and crime. Additionally, cross-border challenges like pandemics, armed conflict, climate change, biodiversity loss, energy-security and

food-security must be addressed. It is critical for the EU's **open strategic autonomy** to ensure the resilience of critical infrastructure and fundamental societal functions as well as the security of supply of basic goods. To strengthen supply chains and to reduce technological dependence by supporting energy efficiency and circularity, as well as more efficient and less polluting manufacturing processes, are key to Europe's resilience and competitiveness. The cultural and creative industries can play an important role in this context. They promote human development and competitiveness, empower people to take ownership of their own advancement and stimulate the innovation that can drive inclusive sustainable growth.

R&I plays a key role in fostering the EU's growth model as described in the Green Deal Industrial plan[20]. It contributes to enhancing the **competitiveness** of Europe's net-zero industry and creating more quality jobs, bringing new and better solutions for scaling up the EU's manufacturing capacity for the technologies and products required to meet Europe's ambitious climate targets, while respecting planetary boundaries, and decent working conditions, contributing to the zero pollution ambition and ensuring that no person or place are left behind.

It is essential to focus on the health and well-being of people, ensuring not only their access to essential services, in line with the European Pillar of Social Rights and to an effective, inclusive and resilient healthcare system as well as to healthy and sustainable food, but also the fulfilment of fundamental needs as outlined in the Sustainable Development Goals. It requires tackling inequalities, fostering inclusion and cultural diversity to empower people in the transitions. It also requires strengthening democracy and increasing democratic participation as well as protecting the EU, its people and its values.

A strong and trustworthy democracy is key to protect fundamental rights and the rule of law. An unstable context with a severe demographic change and significant mobility and levels of migration requires fostering the inclusion of refugees and migrants into the European society. Making legal migration pathways more sustainable can contribute to addressing shortages of skills needed for the green and digital transitions. An increased understanding of intersectionality and recognition of factors that affect individuals in vulnerable situations is key to build an **inclusive** and democratic Europe leaving no one behind.

20. European Commission, Communication: A Green Deal Industrial Plan for the Net-Zero Age, Brussels, 1.2.2023 COM(2023) 62

HOW WILL THE PILLARS OF HORIZON EUROPE HELP DELIVER ON THE KEY STRATEGIC ORIENTATIONS?

The three pillars of Horizon Europe together with the horizontal part on 'Widening Participation and Strengthening the ERA' are designed to have synergetic impact. The links and complementarity between these four aspects add value to projects and increase the overall effectiveness of Horizon Europe in delivering better impact to society on the three key strategic orientations.

The strategic plan focuses primarily on Pillar II of Horizon Europe. In addition, the strong bridges between pillars and, where relevant, within pillars, call for a broader perspective in the strategic plan, to identify and leverage the reciprocal links between or within the four parts. While the three pillars build on each other, the 'Widening Participation and Strengthening the ERA' part, due to its cross-cutting nature, has an impact on all three pillars, which ultimately also supports the further implementation of the ERA. This chapter focuses on explaining how the different pillars and parts work together in line with the key strategic orientations set out in this strategic plan for 2025-2027.

PILLAR II – GLOBAL CHALLENGES AND EUROPEAN INDUSTRIAL COMPETITIVENESS

Pillar II is made up of six clusters of R&I activities, to maximise integration and complementarities across the respective thematic areas while securing high and sustainable levels of impact for the EU in relation to the resources that are expended. Support to new EU policy initiatives from Horizon Europe does not influence the overall expected impacts.

Cluster 1 – Health

Cluster 1 aims to improve human health and well-being and make healthcare systems more inclusive, accessible, sustainable and resilient to cross-border health threats, demographic change and the impacts of climate change and environmental challenges. Digitalisation and new digital technologies such as AI are key to responding to these challenges, as a tool to accelerate scientific discovery for health issues.

Cluster 1 will continue to improve the understanding of the impacts of climate change and environmental stressors on people's health and well-being and support the development of tools and measures to protect people from these impacts and to combat global health challenges. Cluster 1 will help make the health sector **more just, environmentally friendly** and capable of dealing with climate-related issues, while reducing its carbon and pollution emissions.

Cluster 1 will continue work to develop and stimulate the uptake of **new technologies and digital solutions** to improve healthcare and health systems. This includes using technology to help people better understand and use health information, promote healthier lifestyles, improve pandemic/epidemic preparedness, prevent diseases, provide better diagnoses and more personalised treatments and care solutions, and improve access to health and care systems while making sure that even groups with limited access to good healthcare can benefit. The cluster will help the EU ensure leadership in breakthrough health and medical technologies and achieve open strategic autonomy in essential medical supplies and digital innovations. By collecting and analysing health data across borders and creating human-centred health technologies, including the use of AI, research can improve and personalise medical care for different patients, increasing patient safety and leading to better health outcomes and well-being.

Cluster 1 will help bring about a more resilient, fair and inclusive Europe by reducing the burden of illnesses and disabilities on individuals and communities through better health promotion, disease prevention, treatment, and disease management. Cluster 1 will support work to promote health equity and ensure fair and equal access to innovative, sustainable, affordable and high-quality healthcare for everyone, including vulnerable and marginalised communities.

Cluster 1 will also strengthen Europe's ability to prevent, detect and rapidly respond to cross-border health emergencies by fostering advanced R&I to develop effective, safe and affordable medical countermeasures.

Moreover, Cluster 1 will help increase the **resilience and long-term sustainability** of EU Member States' and Associated Countries' healthcare systems. This involves developing systemic approaches, embedding the digital and the green transitions, and maintaining a highly competitive health industry and a well-trained healthcare workforce in Europe.

Cluster 2 – Culture, Creativity, and Inclusive Society

The cluster aims to make Europe more **resilient, competitive, inclusive and democratic**. It will work with interdisciplinary approaches on measures from preservation to a call to action and engagement. R&I investment will continue to strengthen democracy, increase democratic participation, and protect fundamental rights and the rule of law. Cluster 2 will help produce evidence-based strategies to manage demographic change, mobility, and migration, and

foster the inclusion of refugees and migrants in European society. Activities will help increase social resilience, tackle polarisation and political extremism by contributing to the fight against hatred, antisemitism and conspiracy theories, and build trust in democratic governance.

Cluster 2 will also promote cultural and creative industries and linguistic diversity, paying particular attention to regional specificities and cultural diversity, as this enriches society as a whole. This area will explore the relation between artistic expression, social inclusion, and well-being, particularly among vulnerable individuals, such as older people and populations at risk of isolation. In this context, the link between art, culture and health will be emphasised, contributing to a more resilient and inclusive Europe.

Cluster 2 also aims to increase awareness and understanding of the political, cultural and socioeconomic **challenges caused by environmental crises** and the measures needed to counteract them. It wants to ensure that the transition to a more climate-friendly society and economic model is done democratically and in a fair and inclusive manner. This work will also lead to new ways of governing, and create sustainable growth, which is a prerequisite for building resilient, fair and sustainable societies.

Cluster 2 will continue to promote people's involvement and to build trust in democratic processes to address climate change. It will support innovative and interdisciplinary research that builds on the social sciences and humanities. Additionally, investment will help to: (i) protect cultural and linguistic heritage and landscapes from natural and human-made risks; and (ii) foster sustainable and innovative practices in cultural and creative industries.

Furthermore, Cluster 2 will continue to support the human-centred approach to the **digital transition**. It will address people's concerns and needs in areas like AI and other emerging technologies, while also aiming to capitalise on the positive possibilities brought by AI for the cultural and creative sectors. The effects of these developments on democracy, culture and society will be examined to ensure a fair and inclusive development, understanding the political, cultural and socioeconomic implications of the digital transition, anticipate possible consequences, envision future scenarios and support the development of a fair society.

Cluster 3 – Civil Security for Society

Cluster 3 will continue to work to increase civil security for society, supporting the prevention of preparedness for and resilience to a wide range of threats to internal security, security of individuals, and security of society as a whole.

It will continue to improve the response to disasters of all kinds, including climate-related events, and to enable resilience of critical infrastructure to impacts of **climate change**. It will address environmental crime. It will help understand how to manage borders in case of potential large-scale movements of people, including those caused by environmental stress. It will promote environmental sustainability of security solutions. Cluster 3 aims to guarantee

the **security of digital networks and of the population in the online world**. The goal is to create a secure and trustworthy digital environment by ensuring an open, stable and secure cyberspace as well as secure hardware and software systems. Therefore, Cluster 3 will invest in cybersecurity R&I to strengthen the EU's resilience, protect its infrastructures, and improve its ability to cope with cyber incidents. This will help increase the EU's open strategic autonomy in **cybersecurity**. Cluster 3 addresses **cybercrime** and the developing security threats in a digital age, such as criminal use of AI, to protect Europeans against cyber-enabled crimes. It will also continue to harness the opportunities of new technologies for law enforcement and border management.

Cluster 3 aims to strengthen societal preparedness and **resilience** to disasters and threats of all kinds, whether accidental or intentional, of human origin or caused by nature. It will do this by improving disaster risk management and by involving and providing tools to the general public, local, regional and national decision-makers, and operational responders.

Cluster 3 will improve the preparedness and response to the changing threat landscape of terrorism, corruption, organised crime, and attacks on critical infrastructure, including hybrid threats. This will be done by understanding the threats, including the underpinning societal issues, and by developing tools to prevent, detect and investigate them. R&I activities will also continue to enable resilience of critical infrastructure (e.g. energy, water and food supply, health) in case of physical or cyberattacks.

Cluster 3 will also aim for a seamless border passage for legitimate travellers and goods while ensuring internal security and thus integrity of the Schengen area. This will be done by developing capabilities in the areas of border management, customs and supply chain security, as well as capabilities required for civilian maritime security.

Cluster 4 – Digital, Industry and Space

Cluster 4 aims to both: (i) strengthen Europe's **technological sovereignty and competitiveness**; and (ii) support **the transformation of its industries towards net-zero emissions.** Achieving these two goals involves advancing improving manufacturing technologies so that they can play a key role in: (i) renewable energy; (ii) renewable economies; and (iii) achieving carbon neutrality, circularity, and the zero-pollution ambition. Energy-intensive industrial sectors will be helped to adopt climate-neutral and energy efficient solutions by encouraging investment in net-zero technology. Technological sovereignty for the EU may be achieved by both helping to make EU industries globally competitive and openly collaborating with trusted international partners.

Furthermore, Cluster 4 will continue fostering leadership in **digital and key enabling technologies**, including digital and AI, while ensuring that they are aligned with European principles, values and rights. It will help create a globally competitive European digital sector that can fully play its enabling role for fair green and digital transitions and for increasing

the resilience of society. The success of this strategy will allow Europe to stand out as an innovation leader, fostering standards and openness while reducing technological dependence and enabling its open strategic autonomy. A deeper integration of AI technologies in research, engineering and innovation processes will also be fostered.

This also involves understanding the environmental and societal impacts of digitalisation, as well as exploring future technologies that will drive the next waves of innovation, such as quantum technologies, bio-enabled or two-dimensional materials.

The cluster promotes a trustworthy data economy for public and commercial use and a manufacturing industry equipped with adaptable digital tools, including AI, to increase supply chain resilience. This entails supporting manufacturing technologies, standards, and data availability. It will empower workers, consumers, and the general public to ensure that technology benefits them, while also carrying out initial research to better understand the upskilling and reskilling aspects necessary to harness the twin transitions. Key enablers of this process include: (i) connectivity, resilient communications and accessible digital infrastructure; (ii) advanced software development; (iii) powerful human-centric interfaces such as virtual worlds; and (iv) trustworthy applications, including AI.

To reduce dependence on **critical raw materials**, Cluster 4 will promote innovative solutions for responsible exploration, extraction, processing, refining, recovery, re-use and substitution of raw materials, aiming to reduce environmental impact and increasing the EU's open strategic autonomy. The cluster will also speed up the design, development, production and recyclability of new and innovative materials and composites.

Cluster 4 activities are strongly aligned with the European Green Deal objectives through **digital, space and satellite technologies**. The cluster will also drive modular and standardised designs for sustainable systems both on Earth and in space, helping to develop flexible and eco-friendly space infrastructure. Embracing digitalisation, also in space, will revolutionise satellite design, production and operation. R&I will support Copernicus, Galileo and the European Geostationary Navigation Overlay Service's emergency and security services as well as the development of the secure connectivity satellite constellation IRIS2. R&I will also help to develop more resilient space infrastructure through space situational awareness. Attention will be given to linking data and information applications with other key enabling technologies and social sciences.

Cluster 5 – Climate, Energy and Mobility

Cluster 5 is key to making Europe resilient to **climate change** and to enabling the necessary shift in the energy and mobility sectors towards climate neutrality, taking into account their impact on society and the environment, thus enhancing synergies with the zero pollution and biodiversity objectives. Based on a better understanding of behaviour and interdisciplinary knowledge about developing climate patterns, adaptation, and mitigation pathways, as well as by harnessing the potential of AI technologies to accelerate research, Cluster 5 helps to bring about changes in structures, practices and behaviour, advanced net-zero technologies, and innovative solutions for transitioning to low- or zero-emission energy and mobility systems.

In the energy sector, R&I aims for a just transition. This includes: (i) reducing energy demand; (ii) improving energy efficiency; (iii) integrating renewables; (iv) increasing the deployment of renewables; (v) increasing energy storage and conversion; and (vi) keeping energy use affordable. Regarding mobility, R&I promotes zero-emission transport for passengers and goods, while Europe aims to stay a global leader in accessible, affordable, and inclusive mobility. Upskilling and reskilling of workers in the energy and mobility sectors will be prerequisites for achieving these objectives. Collaboration between R&I actors, industry and social partners is crucial, supported by joint undertakings and partnerships.

Cluster 5 capitalises on the **digital transformation** to accelerate climate neutrality by 2050. This involves improving climate models and energy and mobility services. Digitalisation plays a key role in managing energy from various sources, not only in the power grid but also in district heating, industry, and buildings. In mobility, digitalisation enables connected, cooperative and automated systems for innovative, affordable and environmentally friendly transport. Digitalisation also enables advances in the understanding of the earth system, bridging gaps in climate change prediction.

As energy and transport systems become more complex, **democratic engagement** is crucial for ensuring that changes will be **fair, safe and sustainable**. Cluster 5 empowers people and organisations through better information and by involving them in co-creating and shaping solutions. Holistic approaches will be promoted by accounting for interactions with other policy objectives, minimising trade-offs and strengthening synergies.

Cluster 6 – Food, Bioeconomy, Natural Resources, Agriculture, and Environment

Cluster 6 drives forward the **green transition**. By supporting the European Green Deal, it makes Europe more resilient, competitive, inclusive and democratic. This involves fostering the sustainable use of natural resources in various sectors to respect planetary boundaries and to leave no one behind.

The cluster aims to help put **biodiversity** back on a path to recovery through measures across the whole economy. This involves better understanding and addressing the direct and indirect drivers of biodiversity loss with specific focus on protecting and restoring ecosystems with their wide range of services. It also requires integrating biodiversity aspects into social and economic policies and adopting biodiversity-friendly practices.

The transition to sustainable, low-footprint and inclusive **agriculture and food systems** is a major focus. The goal is to provide safe, nutritious, healthy and affordable food for everyone thus ensuring food and nutrition security. This will involve: (i) making agriculture and food systems sustainable and climate-resilient; (ii) managing natural resources efficiently; (iii) reducing food loss and waste; (iv) increasing agrobiodiversity; and (v) improving animal welfare, soil health, and plant health using the One Health approach[21]. By doing so, the cluster aims to have positive impacts on society, the environment and the climate. Cluster 6 supports **rural communities** and rural areas to foster sustainable development and regeneration.

Cluster 6 aims to promote a **circular economy** by increasing resource efficiency from design to disposal. This entails maximising circular processes to reduce environmental pressures while fostering economic sustainability through responsible consumption and production practices.

The cluster fosters the **bioeconomy** and bio-based systems to replace carbon intensive and fossil based ones, increase stakeholder participation along the value chains, and bring resilience to rural and coastal communities. Sustainable value chains in **bio-based sectors** – converting sustainably sourced biological resources from land (including forestry) and sea into safe and sustainable bio-based solutions – make it possible to move away from fossil resources.

Cluster 6 helps create a **toxic-free environment** where water, air and soil pollution are reduced to levels no longer considered harmful to health and natural ecosystems. It focuses on nurturing healthy ecosystems that are indispensable for planetary health and crucial for various sectors like agriculture, forestry, aquaculture and fisheries.

The cluster plays a role in **climate mitigation** by reducing the emissions from the economic sectors it covers and by increasing sustainable natural carbon sinks. It also supports **climate**

21. 'One Health' is an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals and ecosystems. It recognises that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. For more information, see the WHO factsheet on One Health: https://www.who.int/news-room/fact-sheets/detail/one-health.

adaptation by strengthening the resilience of agriculture, food systems, forestry and the blue economy based on responsible stewardship of biodiversity and water, and with nature-based solutions. The cluster also aims to further the understanding of the ocean's role in the climate system and foster research on polar regions.

The cluster seeks to develop **new governance models** that are aligned with the European Green Deal's goals. This involves fostering the use of environmental observation, sharing of knowledge and employing digital tools for better environmental management, policy and decision making. R&I activities fostering the **digital transition**, including through uptake of AI, will increase the sustainability of agriculture and forestry, food systems, circular and bio-based sectors, the sustainable blue economy, pollution reduction, and climate resilience. Involving relevant actors and deploying social innovations will also help to better address the drivers of change – by ensuring continuous reskilling and upskilling of the workforce in agriculture and environmental goods and services sectors – – that will foster a resilient, sustainable and inclusive development of rural and coastal areas.

Cross-cluster issue: The New European Bauhaus

The European Union is moving ahead with its goals to: (i) achieve climate neutrality by 2050; (ii) reduce net greenhouse-gas emissions by 55% by 2030; (iii) shift to a circular economy; and (iv) protect biodiversity. The New European Bauhaus (NEB) has been a part of this agenda for the past 3 years, leveraging the power of inclusiveness, sustainability, arts and culture for the green transition.

The EU has now put in place a substantial regulatory framework for the green transition and has also mobilised substantial funding. However, the pace of implementation of the changes needed is still slow, and these changes are often implemented in a compartmentalised way. Europe needs to further accelerate the transformation of its industrial value chains in the built environment to increase circularity and climate neutrality.

The NEB is a pioneering movement paying special attention to the built environment, bringing together all types of stakeholders (the general public, universities, research institutes, municipalities, national and regional authorities, architects, artists, communities, and businesses) to promote transformative innovation in support of the Green Deal.

More specifically, the NEB as a cross-cluster issue will focus on the following three R&I components:

- **Circular and regenerative approaches for the construction ecosystem**: This R&I component would look in-depth at transforming the construction ecosystem from a linear to a model based on circularity and regeneration, by focusing on innovative materials and products (e.g. re-use, preparing for re-use, recycling, by-products, alternative sourcing of construction material, focusing on secondary sources, etc.), as well as circular and regenerative design and construction techniques (e.g., built environment as a carbon sink, design for deconstruction, modularity, AI-powered design) also including arts, design and architecture considerations. It will also take into consideration that such transformations also need to be applicable to social and affordable housing.
- **Connecting the green transformation, social inclusion and local democracy**: This R&I component will unlock the potential of the social sciences and humanities, the arts, culture and design to further explore and experiment with the transformative potential of participatory practices and governance models that balance public and private interests. It will also bolster democratic values and inclusion through the involvement of communities in the design of public spaces and common goods in their neighbourhoods, which will also lead to wider social acceptance for the necessary green, digital and social transitions.
- **Innovative funding and financing models in the built environment**: This R&I component explores entrepreneurial activity and innovative funding models, including for circular and regenerative business models, that mitigate the perceived risk associated with solutions in the built environment in support of NEB objectives.

Actions with the potential to contribute to the objectives of the NEB published in clusters or in the context of missions may refer to the NEB and beneficiaries, and funded projects will be invited to join the NEB community. Given the cross-cutting nature of the NEB and of its R&I content, the NEB will be implemented as a cross-cluster issue in the Horizon Europe work programmes for 2025-2027. This R&I component will be complemented by a roll-out component that will be delivered through synergies with other EU programmes, in alignment with both Article 7(7) the of Horizon Europe Regulation and Article 6(4) of the Council Decision on the Specific Programme implementing Horizon Europe. Together, these two components will be referred to as the 'NEB Facility'.

The Joint Research Centre (JRC)

The **JRC**'s work programme on direct actions will support European policy priorities. It will help deliver on the key strategic orientations for R&I by generating supporting knowledge and strengthening the expected impacts. The JRC will offer specific support by providing data and analyses for the design of EU policies and the programming of R&I investment, to maximise the impacts that are being targeted by Horizon Europe.

PILLAR I - EXCELLENT SCIENCE

Taking a bottom-up approach, Pillar I supports frontier research and breakthrough scientific ideas (European Research Council), teams up the best researchers from Europe and beyond and equips them with skills (Marie Skłodowska-Curie Actions) and world-class research infrastructures.

Projects of the **European Research Council's (ERC)** grantees are bottom-up. They are selected on the sole criterion of scientific excellence. The ERC provides long-term funding for ground-breaking, high-risk high-gain/- research that advances the frontiers of knowledge. It strengthens the European Research Area's (ERA) scientific and technological bases and provides a benchmark from which to raise the overall quality of European research and the long term societal and economic resilience of the EU. Results from ERC-funded research can be taken forward to strategic research and innovation projects (Pillar II) or to innovation actions under Pillar III. They can also be used in the Widening Participation and Strengthening the European Research Area part, namely in the context of the Excellence Initiatives.

With a focus on excellence, the **Marie Skłodowska-Curie Actions (MSCA)** support researchers from all over the world at all stages of their careers, boosting their training, skills and career development. They are key to making Europe more attractive to top talent from around the world as well as to retaining excellent researchers in Europe. The actions equip excellent researchers in all research areas with new knowledge and skills as well as with international and intersectoral exposure. The MSCA play a key role in boosting investment in the leading fields of R&I, supporting excellent research, developing skilled researchers across the ERA, building strong communities of research and practice, including in widening countries through the ERA Fellowships. This benefits strategic research under Pillar II and innovation actions under Pillar III. It also benefits Widening actions by helping attract and retain talent and by supporting intersectoral mobility.

Research infrastructures (RI) empower researchers in Europe by supporting and optimising an integrated ecosystem of sustainable, world-class and accessible national and pan-European research infrastructures. They address all user needs – from fundamental knowledge creation to technology development – and support the development of an integrated digital environment for practising open science.

In parallel, challenge-oriented funding **of research infrastructures** will be strengthened in 2025-2027. Together with customised services, this funding will further stimulate the use of research infrastructures across the different pillars of Horizon Europe by enabling stronger connections between the RI destinations and the expected impacts under Pillar II, including those from EU Missions and European Partnerships. Horizon Europe will also support cooperation with industry by facilitating access to and use of RI for industrial research. Horizon Europe will facilitate cooperation between European RI and international counterparts

by pooling the resources and efforts necessary to address challenges such as global health, energy, food and nutrition security, environmental challenges, and climate change.

Research infrastructures will support the green transition by providing the scientific community and industry with easy access to a comprehensive catalogue of user-oriented services to help them conduct cutting-edge research and develop innovations that address emerging challenges related to the European Green Deal. In addition, digital RI will help leverage 'ICT for green' to address climate change. RI will also support the digital transition by delivering a fully operational European Open Science Cloud, providing access to FAIR (findable, accessible, interoperable, reusable) research data and results generated with public support. At the same time, more efforts will be made to upgrade such infrastructures to be fully ready for advanced digital technologies like AI.

PILLAR III – INNOVATIVE EUROPE

Pillar III helps improving the conditions for innovators to flourish at all levels of governance (through the European Innovation Ecosystems), supports the development of innovations to address EU strategic challenges, such as the green and digital transition, and strengthens EU technological sovereignty, particularly in deep tech and breakthrough innovation (through the Europe Innovation Council). It also fosters innovation and entrepreneurship through better education and skills and brings innovative solutions to global challenges to the market (through the European Institute of Innovation and Technology[22]).

The **European Innovation Council (EIC)[23]** supports both bottom-up innovative actions and measures that address the strategic plan's key strategic orientations, in harmony with the expected impacts in Pillar II. Activity under the European Innovation Council in Pillar III builds on and complements activities under Pillar II.

The EIC Pathfinder supports low Technology Readiness Levels (TRL) collaborative projects that are multi-disciplinary with disruptive ideas that fall outside the scope of Pillar II clusters. EIC Transition supports mid TRL projects that build on research results from the ERC, Pillar II and the EIC Pathfinder to develop them into commercially viable innovations. The EIC Accelerator supports individual SMEs and Startups, including with investment, via the EIC Fund. The Quantum Flagship, the Clean Hydrogen Partnership and the Cancer Mission in Pillar II for example, benefit from complementary research and innovation support under the EIC for all stages of technology and market maturity. Further, the new and emerging deep tech opportunities identified and developed through the EIC can inform and/or be taken forward and integrated into activity under Pillar II.

The EIC will focus on deep-tech innovations in line with the priorities of the New European Innovation Agenda, while also supporting other types of innovation, including social innovation.

22. For more information, see the dedicated web page for the European Institute of Innovations & Technology.
23. For more information, see the dedicated web page for the European Innovation Council.

The results of EIC-funded initiatives, for example on emerging technologies and breakthrough innovations, will contribute to the objectives of Pillar II and feed into the evidence base for its future programming. In addition, private (co-)investment will be actively promoted, particularly via the EIC Accelerator, to support the further development of innovations initially funded under the EIC, the European Institute of Innovation and Technology (EIT) via the Fast Track scheme, and relevant national programmes via the Plug-In scheme.

The EIC is also one of the programmes underpinning the Strategic Technologies for Europe Platform (STEP) Regulation[24]. STEP leverages and adds flexibilities to existing EU programmes to strengthen European sovereignty and security by supporting the development or manufacturing of critical technologies in three strategic sectors: clean tech, bio tech, and digital and deep tech.

The **European Institute of Innovation and Technology (EIT)**'s overall objective is to help develop Europe's innovation capacity. In 2025-2027, the EIT will continue to support its Knowledge and Innovation Communities (EIT KICs) to strengthen the innovation ecosystems and encourage innovation and entrepreneurship by boosting the innovative and entrepreneurial skills of both individuals and organisations. Stronger skills of those working in R&I should, in turn, help bring new solutions to global challenges to the market.

The **EIT** complements Horizon Europe Pillar II actions by bringing together excellent organisations from business, education and research (the 'knowledge triangle'), to form sustainable, open and dynamic partnerships. These partnerships (EIT KICs) help create novel solutions and technologies for the green and digital transition, and a more resilient, competitive, inclusive and democratic Europe. In accordance with its 2021-2027 Strategic Innovation Agenda[25], the EIT will continue coordinating and creating synergies with and across the EIT KICs – EIT InnoEnergy, EIT Digital, EIT Climate-KIC, EIT Health, EIT Raw Materials, EIT Food, EIT Urban Mobility, EIT Manufacturing and EIT Culture & Creativity. Furthermore, to address new and emerging global challenges, the EIT will launch in 2026 a new KIC Water, Marine and Maritime Sectors and Ecosystems[26].

The EIT will continue to provide support to Pillar II of Horizon Europe, particularly to address innovation at systemic level, along the entire value chain – from education to market roll-out and societal implications. In 2025-2027, the EIT KICs will continue to contribute to the relevant missions, thematic clusters, and other European Partnerships by supporting demand-side measures and providing services that boost technology transfer and accelerate commercialisation in their respective areas. EIT KICs provide an excellent environment for small, fast growing and innovative companies and help them create new business opportunities and/or validate and scale up their value proposition.

24. Regulation (EU) 2024/795 of the European Parliament and of the Council of 27 February 2024 establishing the Strategic Technologies for Europe Platform (STEP)
25. See EIT's Strategic Innovation Agenda for 2021-2027
26. The launch of this new KIC is subject to a positive outcome of the Commission ex-ante analysis evaluating the relevance of the Water, Marine and Maritime Sectors and Ecosystem field, as foreseen in the Decision 2021/820 of the European Parliament and the Council of 20 May 2021 on the Strategic Innovation Agenda of the European Institute of Innovation and Technology (EIT) 2021-2027: Boosting the Innovation Talent and Capacity of Europe and repealing Decision No 1312/2013/EU.

The European Innovation Ecosystems[27] (EIE) will help set up regional innovation valleys by building on strategic areas of regional strength and specialisation. The EIE will also increase social innovation initiatives and citizen empowerment in the context of the green transition by building on strategic areas of regional strength and specialisation. The EIEs will also consider further actions to foster experimentation and support regulatory 'sandboxes' and innovation procurement, in part to bolster national initiatives that pursue similar goals to the EIE. The EIE will create more connected and efficient innovation ecosystems to support the scaling-up of companies, encourage innovation and stimulate cooperation among national, regional and local innovation actors. Thereby, the policy coordination and networking activities of the EIC Forum, links between the EIC and EIT activities and between other pillars of Horizon Europe will be used. This includes the Interregional Innovation Investments (I3) instrument (European Regional Development Fund) under Cohesion Policy and the regional Smart Specialisation Strategies.

The EIE supports the New European Innovation Agenda. In particular, it will help national and regional authorities strengthen and interconnect their innovation ecosystems, by supporting joint interregional innovation programmes in line with the key strategic orientations. It will ensure the inclusiveness of innovation ecosystems by supporting social and technological innovations and innovators, as well as underrepresented groups such as women. These initiatives will specifically address the most pressing global challenges outlined in the New European Innovation Agenda. It will continue to support the European Partnership on Innovative SMEs with its objectives of improving knowledge transfer and access to finance for innovative European SMEs and helping them to access new international markets. Moreover, the EIE will strengthen cooperation with other EU initiatives that focus on innovation such as Startup Europe, the GovTech community, Digital Innovation Hubs or the Enterprise Europe Network and contribute to the development of advisory tools enhancing innovation capacity and potential of companies.

WIDENING PARTICIPATION AND STRENGTHENING THE EUROPEAN RESEARCH AREA

The Widening Participation and Strengthening the European Research Area part (WIDERA) supports the priorities set out in the Pact for Research and Innovation in Europe and the ERA policy agenda[28] and seeks to increase the involvement and success rate of participants from the Widening countries and the outermost regions, helping them get closer to the EU average.

WIDERA supports the key strategic orientations of Horizon Europe by building up Europe's R&I capacity to address global challenges and boost its future competitiveness. The ERA part also supports the uphold, the further uptake and spreading of shared EU values and

27. For more information, see the dedicated web page on European Innovation Ecosystems.
28. European Commission, European Research Area Policy Agenda, overview of actions for 2022-2024.

principles such as ethics in and integrity of R&I, freedom of scientific research, societal responsibility, gender equality, equal opportunities, diversity and inclusiveness. The widening part is Horizon Europe's tool to help reduce the gap in R&I performance between countries and to promote systemic reforms and transformations, including through foresight and intersectoral collaboration.

To increase the impact of Horizon Europe, narrow the innovation gap, and promote excellence, competitiveness and innovation across the ERA, the widening part will strengthen its links with the three pillars. Its activities will be aligned with the priorities set out in the 2021 Pact for Research and Innovation in Europe[29] and be implemented through the ERA Policy Agenda, notably through thematic actions in areas relevant for the clusters.

The first ERA Policy Agenda included actions of relevance to Clusters 2, 4 and 5 (e.g. action 11 – Green energy transformation, Action 12 – Accelerating the green and digital transition of Europe's key industrial ecosystems, and Action 14 – Bring science closer to citizens). These actions have led to two industrial technology roadmaps on low-carbon and circular technologies, which feed into transition pathways of industrial ecosystems.

The first Policy Agenda also includes horizontal ERA actions supporting all clusters (e.g. Action 1 – open access, Action 3 – research careers, Action 5 – gender equality, and Action 8 – research infrastructures) and building the necessary capacity to support successful participation in the R&I process (e.g. Action 16 – Access to excellence).

Action 12 includes the development of a European approach to Technology Infrastructures, which enables technology development and innovation in key industrial sectors, strengthening the European Research Area (ERA). Together with Research Infrastructures in Pillar I, they form the continuum of research facilities and services supporting the entire innovation cycle from research to market, covering all technology readiness levels. Due to their testing, experimentation and demonstration capabilities, services and competencies, Technology Infrastructures bridge the gap between science and innovation supporting industrial capacity building, accelerating the deployment of R&I results and strategic technologies in industrial ecosystems. New activities will be tested under the Horizon Europe pillars implementing the preparatory work of the 2022-2024 ERA Policy Agenda, in support of key EU policy priorities such as Europe's technological sovereignty, competitiveness, and the green and digital transition of industry.

In 2025-2027, synergies will be created between the ERA Policy Agenda and the Horizon Europe work programmes to ensure that both the Pact for R&I priorities and Horizon Europe's key strategic orientations are implemented effectively and coherently. The second ERA Policy Agenda is therefore expected to include significant thematic actions that contribute directly to achieving the impacts expected under Pillar II as well as horizontal actions relevant for all

29. Council Recommendation (EU) 2021/2122 of 26 November 2021 on a Pact for Research and Innovation in Europe.

the clusters, such as boosting links between science, society and education and strengthening the research dimension of the European Universities initiative, including within the smart specialisation process.

The widening component aims to tackle the R&I gap to move towards a truly integrated and cohesive European R&I ecosystem in the EU. Disparities between R&I leading and lagging countries should be tackled through structural policy reforms aimed at, e.g. improving the attractiveness of research careers, internationalisation, effectiveness of management and governance of R&I institutions or matching activities with EU initiatives (e.g. seals of excellence). Greater intersectoral cooperation between research institutions and business is key to bridging these disparities between countries. By building on 'pockets of excellence' and connecting them to broader ecosystems, this component will help countries with less advanced R&I systems to upgrade their R&I systems and performance, allowing the EU to level up.

In 2025-2027, the widening part will be tailored towards greater: (a) inclusiveness; (b) R&I capacity; and (c) sustainability of actions. This will be implemented through a well-balanced mix of the continuation of proven and the introduction of new actions.

EUROPEAN PARTNERSHIPS

Horizon Europe has brought about a major reform and rationalisation of the European Partnership landscape, reducing the number of partnerships from about 120 under Horizon 2020 to 49 under the first Horizon Europe strategic plan. Horizon Europe also introduced a more coherent, transparent, and strategic approach to partnerships based on a clear set of partnership life-cycle criteria as set out in Annex III of the Horizon Europe Regulation. In line with the legal base, all partnerships have been developed in areas where there is strong potential to develop critical mass in a strategically relevant sector, and where a European Partnership approach should be more effective in achieving the objectives of Horizon Europe than regular work programme calls.

To date, more than EUR 65 billion have been committed to European Partnerships: EUR 24.8 billion from Horizon Europe and EUR 35.6 billion from non-EU partners. More than 65% of the total amount has been provided by private sector partners[30]. Partnerships under Pillar II have so far accounted for 39.7% of the pillar's overall budget. The maximum contribution of Pillar II to partnerships is limited to 49.9% of its total budget in line with Horizon Europe's legal base[31].

While co-funded and co-programmed European Partnerships are covered in the strategic plan, institutionalised partnerships require a separate legal base and are therefore not covered by the plan[32].

In the first strategic planning period, institutionalised European Partnerships accounted for the biggest share of the Horizon Europe partnership budget (57%). Of the institutionalised partnerships, the largest share of the budget was dedicated to 10 joint undertakings (based on Article 187 of the TFEU). Co-programmed partnerships accounted for 33% of the Horizon Europe partnership budget, and co-funded partnerships for 10%[33].

By pooling and mobilising resources and encouraging collaboration to achieve common objectives, partnerships are at the heart of the twin green and digital transitions and increasing the EU's resilience. As for the first 49 partnerships under Horizon Europe, 67% of their collective resources are allocated to R&I contributing to the European Green Deal, 36% will contribute to resilience objectives, and 33% to digital objectives[34]. These percentages have increased significantly compared to Horizon 2020. Moreover, European Partnerships have been facilitating and promoting international collaboration with strategic partners in countries and regions outside the EU.

30. These figures are based on commitments made by partners in advance. Actual contributions can only be determined reliably after the end of the initiative.
31. It should be noted that this is a legally binding ceiling, not a target
32. A review of possible areas of action for institutionalised European Partnerships (based on Art. 185 and 187 of the Treaty on the Functioning of the European Union) was carried in 2023 (SWD(2023)260). Priorities for Knowledge and Innovation Communities (KICs) under the European Institute for Innovation and Technology (EIT) are set out in the EIT's Strategic Innovation Agenda for 2021-2027.
33. Performance of European Partnerships: Performance of European Partnerships: Biennial Monitoring Report (BMR) 2022 on partnerships in Horizon Europe in Horizon Europe.
34. Ibid. Partnerships can contribute to different objectives simultaneously, as they are not mutually exclusive.

The following co-programmed and co-funded European Partnerships have been identified for the second Horizon Europe strategic plan. They will appear in the Horizon Europe work programmes, subject to fulfilment of the selection criteria at the moment the work programmes are adopted. Otherwise, the priority will be addressed by traditional calls.

CO-FUNDED EUROPEAN PARTNERSHIPS

- Brain Health
- Forests and Forestry for a Sustainable Future
- Raw Materials for the Green and Digital Transition
- Resilient Cultural Heritage
- Social Transformations and Resilience

CO-PROGRAMMED EUROPEAN PARTNERSHIPS

- Innovative Materials for the EU
- Solar Photovoltaics
- Textiles of the Future
- Virtual Worlds

MISSIONS

EU Missions are flagships of Horizon Europe. Their aim is to channel efforts and actions across programmes and actors to support a limited number of well-defined, urgent and bold global challenges that have the potential to garner the engagement and support of policymakers, stakeholders and the wider public. Following a preparatory phase, in 2021 five EU Missions were launched: Adaptation to Climate Change; Cancer; Restore our Ocean and Waters; Climate-Neutral and Smart Cities; and a Soil Deal for Europe.

A 2023 assessment[35] confirmed that during their first 2 years, EU Missions have supported the EU's work on the European Green Deal, making Europe fit for the digital age, and Europe's Beating Cancer Plan. Since their inception, EU Missions have demonstrated their potential to accelerate change: They break silos, support the implementation of policies and the shaping of policy actions, and allow for flexibility and experimentation. At the same time, EU Missions promote a large-scale mobilisation of stakeholders, leading to a quicker and wider deployment of new approaches and technologies by fostering greater collective ownership. Supported primarily by Horizon Europe funding, they have also connected and supported EU policies and programmes with local action and stakeholder engagement and are on track to achieve their ambitious goals by 2030.

In 2025-2027, more work will be done to ensure that missions successfully shift from their initial phase to deployment and impact. First, a strengthened and better coordinated administrative governance will enable missions to be effective. Horizon Europe investment will help strengthen joint support functions ('back office' tasks) for all current and future EU Missions to facilitate access to resources and actions to achieve mission objectives. Second, a broader portfolio of instruments will be mobilised, including public-private partnerships and the public procurement of innovation. While Horizon Europe funding will guarantee continuity and help to maintain the pace of mission implementation, diversifying funding and financing sources is crucial to support a pipeline of activities from research to deployment. The interdisciplinary nature of the governance mechanisms offers ample opportunities for building synergies between the EU Missions and other parts of Horizon Europe, the EU Missions and other EU instruments and the EU Missions and national, regional and local policies and funding programmes.

Achieving the goals of individual EU Missions will ultimately hinge on broad public support and acceptance of the necessary green and digital transitions. Horizon Europe will support additional efforts to raise awareness on mission impacts, to strengthen stakeholder feedback mechanisms and to increase the visibility of the missions and their concrete actions on the ground. To this end, communication with relevant stakeholder groups and the general public will be stepped up significantly.

35. See the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'EU Missions two years on: assessment of progress and way forward' (COM(2023) 457) and the staff working document accompanying the Commission's Communication on the assessment of the Missions, SWD(2023) 260.

INTERNATIONAL COOPERATION

As laid out in the 'Global Approach to Research and Innovation, Europe's strategy for international cooperation in a changing world'[36] and in the report on the implementation of the Global Approach to research and innovation[37], the EU maintains its commitment to promote responsible internationalisation by preserving openness in international cooperation, based on mutual benefits, respect of fundamental principles and values as well as, where appropriate, reciprocity, while safeguarding when necessary, the Union's strategic interests. This is also in line with the Joint Communication on a European Economic Security Strategy[38].

The pandemic and the global geopolitical situation have highlighted the interdependence between R&I ecosystems, countries, and regions in the areas of global health, critical materials and supply chains. Moreover, addressing health, climate change, biodiversity loss, pollution and other environmental challenges, and protection of cultural heritage requires identifying and implementing solutions at global level, where international cooperation is essential.

The EU's approach to international cooperation will continue to focus on openness of Horizon Europe and multilateralism, combined with strategic targeted actions with key partners from outside the EU. In this way, the EU will ensure the success of the Global Gateway., the European Union's strategy to better connect the world.

Actions set out in the Horizon Europe strategic plan for 2025-2027 will remain open to participation of legal entities from non-EU countries. Participation may however be limited

36. Communication from the Commission on the Global Approach to Research and Innovation. Europe's strategy for international cooperation in a changing world, COM(2021) 252, 18.5.2021.
37. Report from the Commission to the Council and the European Parliament, First biennial report on the implementation of the Global Approach to research and innovation, COM(2023) 356I, 29.6.2023.
38. Joint communication to the European Parliament, the European Council and the Council on 'European Economic Security Strategy', JOIN(2023) 20, 20.6.2023.

where appropriate and duly justified, to protect the EU's strategic assets, interests, autonomy and security[39].

This balanced approach will help to promote a global level playing field. Work together with the Member States and stakeholders on research security to counter foreign interference and to promote multilateralism and responsible internationalisation is also key, including through the Multilateral Dialogue on shared values and principles for international cooperation.

Stronger R&I efforts to develop and deploy net-zero technologies will be pursued in close cooperation with third countries in an open but assertive approach, as per the European Green Deal industrial plan. The EU will also continue its leading role in multilateral health, climate and environmental agreements, initiatives and organisations.

Where European Missions and Partnerships would benefit from international cooperation, support from non-EU countries and international organisations may also be mobilised to achieve their objectives.

In combination with relevant EU policies, R&I cooperation actions with priority countries and regions will continue to help deliver the EU's external policy objectives. These actions will include current Horizon Europe initiatives such as: (i) the Africa Initiative (based on the African Union-European Union Innovation Agenda); (ii) the Mediterranean Initiative; (iii) a new EU-Latin American and Caribbean Initiative[40]; (iv) the Partnership for Research and Innovation in the Mediterranean Area (PRIMA); (v) activities to support the Ukrainian R&I ecosystem in line with evolving needs; and (vi) joint research activities to support the implementation of the EU-India Trade and Technology Council. Topics contributing to these initiatives will encourage the participation of entities from the regions identified.

Association to the framework programme[41] is the strongest form of international cooperation. The association of countries with a strong science and innovation profile and that share fundamental values and principles (located both in Europe and beyond), provides further impetus for the EU to tackle global challenges and address key EU objectives related to the green and digital transition. It is also an efficient way to bring additional funding to the programme. Furthermore, the association of some of the EU's key global allies will strengthen alliances in the face of the ever-harsher geopolitical situation.

39. In line with Article 22(5) of the Horizon Europe Regulation.
40. Joint Communication to the Parliament and the Council, A New Agenda for Relations between the EU and Latin America and the Caribbean, JOIN(2023) 17, 7.6.2023.
41. For the list of Associated Countries, please check the dedicated page on Association to Horizon Europe.

International cooperation will continue to take a variety of complementary approaches:

- **Further association agreements with eligible third (i.e. non-EU)** countries to provide entities of these countries, as far as possible, full access to the calls and actions (within the scope of association)
- **Collaborative research and innovation initiatives**, including targeted initiatives and projects with partners from key non-EU countries and regions in strategic areas of mutual benefit and strategic interest under all clusters, as well as the EU Missions and the European Partnerships.
- **International mobility and cooperation in frontier research** and support to brain circulation and the internationalisation of EU innovative companies, in particular through activities in Pillars I and III.
- **EU participation and leadership in multilateral alliances**, to gain access to and share research and observation data on global challenges such as cybersecurity, climate change, sustainable food and nutrition security, biodiversity loss, environmental degradation, transition to a circular global economy, global health issues as well as ocean governance and polar research.
- **Policy dialogues with non-EU countries and regions** to reinforce and facilitate international cooperation at a strategic level, by agreeing on fundamental values and principles for international cooperation in R&I including issues such as academic freedom, research ethics and integrity, gender equality and diversity, open science and research excellence.
- **Policy dialogues with Associated Countries in the EU's neighbourhood** will help these countries to align with European Research Area objectives and actions, which, for accession countries is an important step towards their alignment with the EU acquis on science, research and innovation.
- **Using science diplomacy action to tackle geopolitical challenges** in a fragmented multipolar world, making European diplomacy more strategic, effective and resilient, and extending the EU's global outreach and impact.

RESEARCH SECURITY

The European Economic Security Strategy adopted in June 2023[42] aims to strike a balance between preserving its economic openness and dynamism while safeguarding research security. Economic security can be achieved by promoting the EU's economic base and competitiveness, protecting against risks and partnering with the broadest possible range of countries to address shared concerns and interests.

Improving research security is key to protecting the EU's open strategic autonomy by ensuring a systematic enforcement of the existing tools and identifying and addressing any remaining gaps. The following measures under the Horizon Europe Regulation contribute to this:

- Horizon Europe Regulation provides for the **possibility to limit participation** to safeguard EU strategic assets, interests, autonomy or security (Article 22(5)). It is also possible to set additional eligibility criteria in the work programme (Article 22(6)) that are justified by policy requirements or the nature and objectives of the action.
- All actions funded under Horizon Europe must comply with the applicable **security rules**, in particular the rules on the protection of classified information against unauthorised disclosure (Article 20). To this end, a **security appraisal** can be carried out to determine whether research proposals raise security issues.
- Regarding the results of Horizon Europe funded projects, the Commission or other funding bodies can **object to transfers of ownership or grants of an exclusive licence** to entities established in a non-associated non-EU country. This applies up to 4 years after the end of the action if the transfer is 'not in line with Union interests' (Article 40(4)).

These measures are complemented by additional actions addressed to the R&I sector in the EU:

- The **toolkit on tackling foreign R&I interference**[43] aims at helping to raise awareness and build resilience in the R&I sector across Europe to underpin research security more broadly. In addition, the **Code of Practice on the management of intellectual assets for knowledge valorisation**[44] is a very useful guide for R&I cooperation and promotes a role for facilitators to assist partners involved in international collaboration initiatives.
- The Commission proposal for **Council Recommendations on research security** adopted by the Commission on 24 January sets out **guiding principles for responsible internationalisation**, including: (i) key policy actions at national and sectoral level to increase research security; as well as (ii) initiatives at EU level to support the efforts of the Member States and the R&I sector.

42. Joint Communication to the European Parliament, the European Council and the Council on European Economic Security Strategy, 20.6.2023, JOIN(2023) 20 .
43. European Commission, Directorate-General for Research and Innovation, Tackling R&I foreign interference – Staff working document, Publications Office of the European Union, 2022.
44. Commission Recommendation (EU) 2023/499 of 1 March 2023 on a Code of Practice on the management of intellectual assets for knowledge valorisation in the European Research Area.

SPECIFIC ISSUES

A number of important, specific cross-cutting issues should be considered when implementing Horizon Europe in 2025-2027. These cross-cutting issues, which aim to create a sound foundation for following the key strategic orientations described above, have been revised in the light of new developments since the adoption of the first Horizon Europe strategic plan.

BALANCE BETWEEN RESEARCH AND INNOVATION

All key strategic orientations require R&I activities at different stages of maturity.

Product and process innovations contribute to economic and societal impact pathways. They are important for open strategic autonomy and sovereignty in industrial value chains and can be described in terms of technology readiness levels (TRLs). However, some knowledge-generating activities with a societal and scientific impact go beyond the technology based TRL logic. Nevertheless, they lay the foundation for the next generation of technologies and are also crucial for societal transformation processes. R&I activities for societal transitions require recognising wider groups of innovation stakeholders such as civil society, public services and local administrations, and their innovation needs and opportunities.

The 2025-2027 Horizon Europe work programmes will be designed to provide a balanced support to activities with a range of maturity and of technology readiness levels, ranging from knowledge-generating and early-stage research to innovation, demonstration and first deployment activities, such as in model regions, living labs and lighthouses. Collaborative research projects with low technology readiness levels and maturity levels are also key for more impactful and innovative outcomes and will be strengthened in Pillar II. The 2025-2027 Horizon Europe work programmes and their support to intergovernmental actions like COST and EUREKA will aim to provide more opportunities for collaborative, knowledge-generating activities.

To make the role of knowledge-generating activities more visible and provide additional opportunities, topics will better describe inherent societal, non-technological elements of expected outcomes while refraining from describing activities or outputs of projects to be funded. In this context, the Commission will work towards developing an approach as regards when and how societal readiness should be considered and aims at testing it in selected topics. This concept implies an interdisciplinary approach to projects, involving greater sensitivity and consideration about whether research and innovation match societal needs.

Efforts will also be made to include more open and less prescriptive topics as well as a range of expected project sizes.

THE INTEGRATION OF SOCIAL SCIENCES AND HUMANITIES

The increasing complexity of emerging phenomena cannot be fully understood or addressed from within knowledge silos, and requires confrontation and collaboration between diverse methods and approaches to the study of the same issue. Knowledge from social sciences and humanities (SSH), including arts, is particularly important to explore different meanings and dimensions that global challenges bring with them and to foster reflexivity over the methods through which they are enquired. SSH is fundamental for paving the way to interdisciplinary collaborations, with knowledge of science, technology, engineering, and mathematics (STEM), while maintaining a human-centric focus. Original approaches need to be tested to support the uptake of interdisciplinary skills for the future, from basic education that fosters critical knowledge and an open mindset to vocational training for the (re-) and (up-) skilling of the workforce.

Effectively integrating SSH into all clusters, including all missions and partnerships, is a key principle of the programme.

SSH are a key part of R&I, especially for the twin green and digital transitions and demographic change. This is reflected by flagging specific topics and requesting an assessment of their societal impact. SSH will be integrated into such projects, from their drafting to their selection and evaluation by evaluators with demonstrable SSH expertise.

THE ROLE OF KEY ENABLING TECHNOLOGIES IN SCIENCE, INNOVATION AND STRATEGIC VALUE CHAINS

Europe's industry faces multiple challenges including increasingly knowledge-intensive production, meeting the needs of the twin green and digital transitions and enabling the EU's open strategic autonomy and global leadership. Key enabling technologies[45] (KETs) are key to responding to these challenges, crucial for Europe's strategic value chains and for applications in health, energy, mobility and biomanufacturing. They therefore need to be developed across a broad range of technology readiness levels.

Developing and mastering KETs can contribute towards EU industrial leadership in global markets, solving global challenges and achieving a sustainable, circular and climate-neutral EU economy. Small and medium-sized enterprises (SMEs) tend to use KETs less frequently and less effectively than larger companies (an issue that cannot be addressed by Horizon Europe actions alone) and therefore lose out on the potential they bring. Efforts will be made to allow SMEs to profit from KET topics.

45. The key enabling technologies of the future include advanced materials and nanotechnology; photonics and micro- and nano-electronics; life-science technologies; advanced manufacturing and processing; AI; digital security; and connectivity.

KETs also have the potential to foster future jobs for Europeans. In addition, artificial intelligence and digital security, connectivity and good legal and economic frameworks are impacting all parts of society with repercussions for R&I. Special attention will also be paid to responsibly harnessing AI technologies' potential to accelerate the productivity of the research sector and keep the EU as a major scientific global player

All the clusters will develop and apply key enabling and emerging technologies as part of the common strategy to promote the EU's industrial and social leadership – both as general-purpose technologies and as sector-specific enablers. Moreover, Pillar I of Horizon Europe, 'Excellent Science' will contribute to relevant scientific breakthroughs and the research infrastructures needed to develop KETs at their earlier phases, including for Artificial Intelligence applications in different scientific fields, while developing KETs in later phases will be supported by pilot projects on Technology Infrastructures. Pillar III, 'Innovative Europe', will support breakthrough innovations based on KETs, such as quantum technologies and photonics towards higher TRL and industrial deployment.

GENDER EQUALITY AND INCLUSIVENESS, INCLUDING THE INTEGRATION OF GENDER CONCERNS INTO R&I

Gender equality is a cross-cutting priority in Horizon Europe and concerns all programme parts. Activities will aim to eliminate gender inequality and intersecting social inequalities – including those based on age, disability, ethnic or racial origin, and LGBTIQ identity – throughout R&I systems, including by addressing unconscious biases, stereotypes, and systemic structural barriers.

Integrating the gender dimension into R&I content will continue to be a default requirement across the whole programme[46] unless a topic specifies otherwise, or applicants can duly justify its non-relevance. This integration is particularly relevant for addressing global challenges, including in areas such as biomedicine and healthcare, online violence, artificial intelligence and robotics, as well as climate change mitigation and adaptation, in which sex and/or gender differences play pivotal roles, thereby influencing the quality and societal relevance of R&I outcomes.

ETHICS AND INTEGRITY

Ethics and research integrity are prerequisites for research excellence, for public trust in science and for the science-policy interface. They are also critical for delivering human-centred green and digital innovations that incorporate European values. Horizon Europe will continue to promote the European Code of Conduct for Research Integrity, to require

46. Unless the topic description explicitly states that the integration of the gender dimension (sex and gender analysis) in a research and innovation content is not a mandatory requirement, or unless the applicants duly substantiate in their application why sex or gender are not relevant variables for their specific proposal – cf. the Horizon Europe Programme Guide and RIA/IA application forms.

full adherence to ethical principles, fundamental rights and applicable legislation, and to integrate an 'ethics by design' approach into all relevant Horizon Europe actions. To prevent ethics dumping, Horizon Europe will not fund practices that would breach EU rules, even when implemented outside the EU.

Horizon Europe will continue to lead the way in addressing the ethical dimension of new and emerging technologies (e.g. artificial intelligence, neuromorphic engineering and computing, new genomic techniques, biomedical and geoengineering, space exploration, synthetic biology, neurotechnology) and their potential societal impact, as well as their impact on the planet, on ecosystems and living conditions of the next generations, in particular in the context of the green and digital transitions and the ambition to improve human health and well-being. Actions will cover the promotion of the necessary societal dialogue including with the science for policy ecosystem, engagement with the general public, strengthening of dialogues on ethics and integrity in research with global partners, and building a constructive culture of 'doing good' beyond 'doing no harm', a fundamental principle of the European Research Area.

To solidify the EU's commitment to the highest standards of ethics and integrity, Horizon Europe will support and further develop innovative actions for training, education and capacity building, as well as operational procedures and promotion plans supporting the research community, institutions, funders and ethics/integrity bodies. This includes support for the reform of the researchers' assessment process and the evaluation of research institutions.

DISSEMINATION AND EXPLOITATION OF RESULTS

Every year, EU-funded researchers produce a considerable number of research results. For these results to benefit society, they must be made available to the relevant stakeholders and used to generate actual societal and/or economic impact.

Only by disseminating and actually using excellent research results will the EU be ready to face the future. Dissemination and exploitation[47] (D&E) are key to supporting the translation of results into knowledge, goods and services of economic and societal value. Horizon Europe projects bridge the gap between research and impact by using their results for market uptake, wider scientific use or advice for policymaking in service of society. The EU's excellence in knowledge stemming from research and innovation should translate into value that benefits society.

In this line, and in order to increase knowledge valorisation in the Union, the Council has adopted Recommendation on the Guiding Principles for knowledge valorisation[48] to provide a common policy framework in the Union and help Member States align their initiatives for R&I value creation. These guiding principles are implemented in Codes of Practice, which provide

47. For more information, see the dedicated page on Dissemination and exploitation of research results.
48. Council Recommendation (EU) 2022/2415 of 2 December 2022 on the guiding principles for knowledge valorisation,(OJ L 317, 9.12.2022, p. 141).

guidance to help researchers, innovators and other stakeholders improve the valorisation of R&I results [49].

The European Commission has a D&E strategy in place to support valorisation of R&I results from Horizon Europe. Notably, Horizon Europe provides a wide range of guidance, tools and opportunities to incentivise beneficiaries and provide them with practical support, in the form of integrated services, for their D&E activities - both during and after a project's lifetime. Services include: (i) the Horizon Results Platform[50] which offers matchmaking and networking opportunities for EU-funded research results; (ii) the Community Research and Development Information Service (CORDIS)[51] - the Commission's results hub for EU-funded R&I projects; (iii) the Horizon Results Booster[52] which provides specialised consultancy services to increase the impact of research results; (iv) the Standardisation Booster[53] which provides expertise on the creation or revision of standards; (v) the European IP Helpdesk[54] which offers advice on intellectual property management; and (vi) recognition initiatives, including in combination with other EU programmes.

The dissemination and exploitation of the results of EU-funded projects feed into EU policy-making through a Commission-wide scheme to collect and utilise results relevant to policy-making at the EU level, at the Member State level, and in the Associated Countries.

This includes independent scientific advice on specific policy challenges provided by the European Commission's Group of Chief Scientific Advisors. This Group also refers to comprehensive reviews of available scientific evidence provided by the consortium of academy networks, SAPEA[55].

Science for Policy is an initiative designed to strengthen the role and impact of science for evidence-informed policymaking and to explore ways of fostering this approach across Europe by providing EU policymakers, Member States and Associated Countries with access to timely, relevant, and high-quality scientific evidence and advice to help inform policymaking and engage in co-creation. The Commission helps Science for Policy stakeholders to connect and cooperate, both among themselves and at European level by promoting a regular policy dialogue aiming to encourage the mobilisation, reinforcement and coordination of existing structures and the development of a network of Science for Policy coordinators, while respecting specific national circumstances.

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49. Commission Recommendation (EU) 2023/499 of 1 March 2023 on a Code of Practice on the management of intellectual assets for knowledge valorisation in the European Research Area.
50. More information can be found on the dedicated page on the Horizon results platform.
51. Cordis EU research results platform.
52. Horizon Results Booster.
53. Horizon Standardisation Booster.
54. Commission Recommendation (EU) 2023/499 of 1 March 2023 on a Code of Practice on the management of intellectual assets for knowledge valorisation in the European Research Area and Commission recommendation (EU) 2023/498 of 1 March 2023 on a Code of Practice on standardisation in the European Research Area.
55. Science Advice for Policy by European Academies (SAPEA). SAPEA, funded by Horizon Europe, brings together outstanding expertise from: (i) the natural sciences; (ii) engineering and technology; (iii) medical, health, and agricultural sciences; (iv) social sciences; and (v) humanities. It draws on the work of over 120 research organisations and associations of experts across Europe. It also draws on all available evidence, including from research projects funded by Horizon Europe and the ERC.

OPEN SCIENCE PRACTICE

Horizon Europe will continue to support and mainstream open science as the gold standard for R&I activities. This method involves openly sharing knowledge, data and tools as early as possible with all relevant knowledge actors and society. The aim is to increase the quality and impact of R&I, support the dissemination of knowledge and improve responsiveness to global challenges.

The Horizon Europe Regulation makes key open science practices mandatory, namely open access to scientific publications, and implementing responsible management of research data in line with the FAIR principles of 'findability', 'accessibility', 'interoperability' and 'reusability', notably through the obligations to develop data management plans and to ensure open access to research data.

The different parts of Horizon Europe will also continue to support and incentivise the practice of open science by the R&I communities, through:

- improved interoperability and sharing of data ('as open as possible and as closed as necessary') and enhanced reproducibility of research results, which will in particular be a focus of several clusters, partnerships and missions;
- the involvement of the general public and other end-users through different participatory formats e.g., co-creation and deliberative exercises, citizen science, and user-led innovation modes of R&I, which will be promoted across the programme;
- the development and consolidation of the European Open Science Cloud (EOSC), the development of appropriate skills, and the diffusion and adoption of open science practices, which will be supported further;
- the availability of Open Research Europe (ORE), the open access peer reviewed publishing venue for Horizon 2020 and Horizon Europe beneficiaries, which will develop further, as well as the support to not-for-profit, scholarly open access publishing models.

SOCIAL INNOVATION

The long-term global challenges faced by the EU require solutions that integrate scientific advances, technological innovation, and social and other forms of innovation. Going beyond the technical paradigm, leveraging social innovation gives rise to solutions that prove more adapted and robust. Moreover, such solutions may result in:

- a greater sense of involvement and greater buy-in by citizens, businesses, social partners and public authorities;
- active, democratic participation in the design of effective and meaningful solutions;
- changes in individual behaviour, work organisation and social practices;

- new social relationships, collaboration and governance models; and
- new sustainable business models and social enterprises.

Social innovation is innovation that is social in ends and means. It takes the form of new products, services and business models that simultaneously meet social needs more effectively than alternatives and create new social relationships or collaboration. Social innovation is not only good for society, but also enhances society's capacity to act on common challenges.

Horizon Europe promotes social innovation as inseparable from technological and other forms of innovation. Firstly, because each form of innovation makes a unique contribution. Secondly, because integrating technological, social, and other forms of innovation ensures that innovation empowers society and supports social change on the path to sustainability. This integrating and integrated approach to innovation is centrally supported by the European Group on Ethics in Science and New Technologies (EGE), which delivers independent high-level advice to the European Commission on issues where ethical, societal and fundamental rights issues intersect with the development of science and new technologies. Horizon Europe promotes social innovation as a cross-cutting theme in all its parts. It does so with calls dedicated to social innovation as well as calls that include social innovation elements in their expected outcomes and/or scope.

DO NO HARM PRINCIPLE

In line with the interinstitutional agreement on the 2021-2027 multiannual financial framework[56], implementing the EU budget must do no harm to the EU's environmental policy objectives.

The Commission will carry out a 'do no harm' screening for all topics to be included in the work programmes, as was the case for the 2021-2024 work programmes, looking at expected outcomes and assessing how far they might impact environmental policy objectives.

In addition, under the Horizon Europe ethics appraisal procedure (see also section 7.5), applicants are asked to self-assess ethical aspects of their proposals including information on possible negative environmental effects of their project's objectives, activities or results. The Commission will improve the environmental ethics dimension in the ethics appraisal procedure and provide revised guidance to applicants and scientific evaluates in line with feedback from stakeholders and expert advice. This will allow to better streamline the scientific and ethics assessment procedures of proposals, avoid duplication of information in applications and managing better the risks of possible negative environmental effects.

56. Interinstitutional agreement of 16 December 2020 between the European Parliament, the Council of the European Union and the European Commission on budgetary discipline, on cooperation in budgetary matters and on sound financial management, as well as on new own resources, including a roadmap towards the introduction of new own resources, Official Journal LI 433/28.

SYNERGIES

In the context of EU funding, 'synergies' occur when the impact of the results or programmes as a whole is greater than that of the sum of their individual impacts. This applies to EU programmes as well as transnational, national- and regional programmes. Synergies require close interaction between two or more programmes with the aim of boosting the impact of individual measures. For the strategic plan, the concept of 'synergies' refers to synergies between Horizon Europe and other relevant programmes/funding mechanisms[57]. This differs from complementarities between the clusters in Horizon Europe, that are referred to as 'cross-cluster complementarities'.

Synergies between Horizon Europe and other EU funding programmes are key to achieving greater impact from R&I outcomes in support of Commission priorities. The success of Horizon Europe will be enhanced through synergies with other EU funding programmes, such as demonstration and piloting capacities, specific deployment programmes, dissemination and exploitation strategies, transfer and sharing of knowledge and data, complementary and cumulative funding sources, and accompanying policy measures.

Annex IV of the Horizon Europe Regulation[58] sets out a framework for developing strategic synergies with other EU spending programmes. This is complemented by the Common Provisions Regulation[59], governing the funds implementing cohesion policy. In addition, the importance of synergies is recalled in the specific regulations of several EU funding programmes[60]. The Commission Notice on Synergies between Horizon Europe and European Regional Development Fund (ERDF) programmes[61] gives guidance on how to use funding from the ERDF programmes available at national/regional levels to co-funded European Partnerships in Horizon Europe.

Horizon Europe is striving to foster synergies with other EU programmes by:

- Combining Horizon Europe funding with other EU, national or regional funding instruments in the same operation, project or initiative in order to achieve greater impact and efficiency (**cumulative / complementary funding**).
- Funding collaboration where projects/initiatives build on each other's results/resources (**sequential synergies**). Within this type of synergy, there is a differentiation between:
  - **upstream** synergy, which occurs when regional/national initiatives pave the way for joint efforts to apply for Horizon Europe; and

57. Relevant sources:
    - Annex IV to Regulation (EU) 2021/695 establishing Horizon Europe.
    - the 2022 Commission Notice on 'Synergies between Horizon Europe and ERDF programmes' (2022/C 421/03)(2022/C 421/03)(2022/C 421/03);
    - the 2014 Commission guidance document on 'Enabling synergies between European Structural and Investment Funds, Horizon 2020 and other research, innovation and competitiveness-related Union programmes';
    - the European Court of Auditors' Special Report No 23/2022 'Synergies between Horizon 2020 and European Structural and Investment Funds – Not yet used to full potential'.
58. Annex IV of the Horizon Europe Regulation foresees synergies between Horizon Europe and the listed EU programmes.
59. Regulation (EU) 2021/1060 of the European Parliament and of the Council of 24 June 2021 laying down common provisions on the European Regional Development Fund, the European Social Fund Plus, the Cohesion Fund, the Just Transition Fund and the European Maritime, Fisheries and Aquaculture Fund and financial rules for those and for the Asylum, Migration and Integration Fund, the Internal Security Fund and the Instrument for Financial Support for Border Management and Visa Policy.
60. See for example for the ESF+: Recital 17 of the preamble to Regulation (EU) 2021/1057.
61. Commission Notice on Synergies between Horizon Europe and ERDF programmes (O.J. C421/7 of 4.11.2022).

  - **downstream** synergy aiming to enhance the take-up of Horizon Europe and other research results towards the market and concrete deployment.

- Funding parallel projects that complement each other (**complementary parallel projects**), which also includes funding to improve the R&I capacity to provide the necessary basis for Horizon Europe projects.
- Securing **alternative funding** for proposals that have been submitted to a competitive call for proposals under an EU programme and evaluated as complying with all quality requirements of that programme, but which could not be funded due to budgetary constraints. For example, the Horizon Europe **Seal of Excellence** recognises the value of a proposal and helps other funding bodies to take advantage of the Horizon Europe evaluation process. Seals of Excellence are awarded to project proposals submitted under some Horizon Europe calls. The awarded proposals may be funded under the ERDF, ESF+ or EAFRD. Seal of Excellence projects do not have to go through a regular project-selection process under the relevant programme but must nevertheless undergo at least a simplified assessment.

In recent years, there has been an increasing focus on the development of so-called '**synergies by design**', referring to the intentional creation of synergies in the design of Horizon Europe or other programmes' work programmes and individual calls. Such synergies by design are often used with a view to improve the exploitation of research results coming from Horizon Europe and/or by funding projects building on research results from other programmes[62].

The **EU Missions** are also an ideal testing ground for synergies in the achievement of shared objectives. The EU's centrally managed programmes, like Horizon Europe, play a mobilising role for new ideas and approaches. These centrally managed programmes also provide a joint, open learning environment where knowledge is pooled and exploited/capitalised on/picked up, and where stakeholders can get inspiration.

Concrete actions that will help maximise synergies include:

- funding parts of an action that already receives a grant from another EU programme or supporting the further uptake/deployment of R&I results that are expected to result from an action;
- awarding Seals of Excellence to facilitate funding under other funding programmes;
- providing explicitly for complementarities between different calls;
- providing for co-funding with another EU programme to mitigate a project's risks, for example through a budgetary guarantee blended with a grant or a financial instrument;
- considering relevant Smart Specialisation Strategies to enhance the possibilities of financing the projects' research results under ERDF programmes and other downstream synergies;

62. One example for the creation of such synergies by design aimed to ensure a smoother link between Horizon Europe and ERDF funding is the incorporation into Horizon Europe funded projects of so-called 'smart specialisation priorities'.

- Making use of 'synergies by design' to improve the exploitation of research results coming from Horizon Europe.

Specific examples of synergies in the clusters of Horizon Europe are include in the cluster impact summaries.

Fostering synergies between Horizon Europe and other programmes will result in:

- more efficient public spending;
- a more effective implementation of programmes and investment (EU, national and private sector) to make full use of research results;
- fostering evidence-informed policy making and support to programming;
- an accelerated innovation cycle.

SPENDING STRATEGIES FOR EU POLICY PRIORITIES

Horizon Europe[63] commits to dedicating at least 35% of its total budget to **climate** objectives. Work on the 2021-2024 work programmes has shown that a sound ex-ante estimation of expenditure is key to fulfilling this objective. Processes to enable this are now well established and the monitoring framework for climate-related expenditure has developed significantly.

However, the ability to react to shortfalls in meeting the 35% target is undermined by the significant interval of time between programming work programme actions and actual implementation of the projects, which leads to delays in reliable monitoring data. The latest estimates based on monitoring data for 2021-2022 indicate that for 2021-2022 35% of the total budget is dedicated to climate objectives. For 2023-24, based on ex-ante estimates and partial monitoring data, the figure is likely to be slightly below 35%. This calls for: (i) maintaining the steering procedures and reducing further, as part of risk management, the over-estimation of the climate aspects of topics; (ii) ensuring that necessary measures are implemented so that the overall 35% target is reached across all 7 years of the programme; and (iii) that the ex-ante estimation of climate expenditures are complemented by ex-post figures for the completed years of the programme.

Reflecting the importance of tackling the dramatic loss of biodiversity, Horizon Europe is committed to raising investment in **biodiversity** to 10% of its total budget for 2025 to 2027. Compared to 2021-2024 this requires more effort in mainstreaming biodiversity and nature-related aspects into areas such as health, environmental crime, societal change, social inequity, digitalisation, and the interplay between cultural heritage, nature and landscape. New approaches are also needed to address the effects of industrial production, material, transport and energy provision on nature and biodiversity.

63. Regulation (EU) 2021/695 of the European Parliament and of the Council of 28 April 2021 establishing Horizon Europe.

Strong institutional partnerships have a key role to play in reaching the target of EUR 13 billion investment in **core digital technologies**[64] in 2021-2027. Within the work programmes of Clusters 1, 3 and 4 certain destinations of work programmes are crucial for that objective and need to maintain ambitions.

In addition to the above spending targets, Horizon Europe should also comply with the interinstitutional agreement of 16 December 2020, which requires the tracking of budget expenditures contributing to **gender equality**[65]. This is part of a broader effort to enhance gender mainstreaming across all EU programmes. A pilot tracking methodology has been developed which builds in particular on the requirement to integrate a gender dimension into all R&I content by default. Although no specific budget allocation target is specified, it remains an integral component of the spending strategies for Horizon Europe.

64. Core digital technologies derive from 'digital key enabling technologies' (including for example chip design, chip-manufacturing technology, photonics, robotics, and cybersecurity) and aim at genuine, application-agnostic technology development. This includes in particular actions and partnerships in Cluster 4, actions in Clusters 1 and 3, and actions under the EIC and the ERC.
65. Interinstitutional agreement of 16 December 2020 on budgetary discipline, on cooperation in budgetary matters and on sound financial management, as well as on new own resources, including a roadmap towards the introduction of new own resources, Article 16(f).

CLUSTER IMPACT SUMMARY

Cluster 1
HEALTH

The objectives and expected impacts defined for Cluster 1 in the first strategic plan (2021-2024) remain pertinent and will be pursued over 2025-2027, with a specific focus on the following challenges and developments.

Building on the **COVID-19 experience** and in support of the objectives of the **European Health Emergency Preparedness and Response Authority (HERA)**, Cluster 1 will invest in pandemic preparedness and response, including in the development of appropriate medical countermeasures and data-driven prevention and prediction measures for serious cross-border health threats, thus providing direct support to the objectives of the **European Health Union**, including the new **regulation on serious cross-border threats to health**.

Cluster 1 will pursue efforts to better understand and mitigate the effects of the **triple planetary crisis** (climate change, pollution and biodiversity loss) on human health and healthcare systems, in line with the EU's environment and health policies, the **European Green Deal** and the EU Climate Adaptation Strategy.

The surge in mental health issues, exacerbated among others by the pandemic, digital stress, the climate crisis, Russia's war of aggression against Ukraine, or socio-economic deprivation, has underlined the need to promote mental health and prevent and treat mental illness. Cluster 1 R&I investment and the co-funded Partnership for Brain Health will support the Commission initiative on a comprehensive approach to mental health[66].

Further investment will also be needed to address EU long-term challenges linked to the ageing population and to the increased burden of **non-communicable diseases** and their co-morbidities. Cluster 1 and several of the European health partnerships will support the 'Healthier together – EU non-communicable diseases initiative'[67]. The **Mission on Cancer** will also contribute to this endeavour while also supporting the policy objectives of Europe's Beating Cancer Plan[68], a major pillar of the European Health Union.

Even when COVID-19 struck, **EU healthcare systems** were already under strain due to long-standing challenges related to demographic changes, the rise of chronic conditions, rising health and care costs, and staff shortages. Cluster 1 will complement the work of the European Partnership on Transforming Health and Care Systems in strengthening the resilience of health systems.

To further boost the digitalisation of healthcare and healthcare systems, R&I will also be needed to leverage the innovation potential of health data and data-driven approaches. **The proposed European Health Data Space Regulation** will help support data-based health research and innovation activities in compliance with the EU's high data protection standards. In addition, the COVID-19 crisis and the disruption of global value chains have highlighted the necessity of **strengthening EU technological sovereignty** not least in the health sector. **The pharmaceutical strategy for Europe** and the proposed revision of the EU general

66. For more information, please check the dedicated page on a comprehensive approach to mental health.
67. For more information, please check the dedicated page on Healthier together – EU non-communicable diseases initiative.
68. Europe's Beating Cancer Plan, Communication from the Commission to the European Parliament and the Council, COM(2021) 44, 3.2.2021.

pharmaceutical legislation (published on 26 April 2023)[69] will warrant R&I efforts to escalate the development and production of innovative health technologies and tools in Europe.

Non-animal new approach methodologies hold great promise to replace or complement animal studies for improving biomedical research, safety assessment of chemicals, or testing of therapies. Cluster 1 will continue its support to the development and validation of alternatives to animal testing.

To ensure a maximum public health impact, Cluster 1 will ensure greater synergy with other EU funding programmes and pursue international multilateral cooperation in line with the EU **Global Approach to Research and Innovation**.

HOW WILL CLUSTER 1 MAKE A DIFFERENCE?

Expected Impacts

Cluster 1 will programme investment to achieve the following six expected impacts.

1. Staying healthy in a rapidly changing society

The expected impact is that people of all ages in the EU stay healthy, resilient, and independent even as society changes fast. This will arise from healthier lifestyles and behaviour, healthier diets, healthier environments, improved evidence-informed health policies, and more effective solutions for health and well-being promotion, disease prevention and monitoring, and rehabilitation.

Research and innovation (R&I) is needed to improve the understanding of health and care needs throughout the life course, including those related to health disparities (e.g. needs specific to age, sex, gender identity/expression, sexual orientation and vulnerable populations). With this knowledge, more personalised, effective, accessible, and affordable solutions can be developed for promoting health and well-being, pursuing health equity, preventing diseases, and for planning, implementing and monitoring care and (re)habilitation. This includes addressing the needs related to chronic health conditions, physical disabilities, mental health issues and disabilities, or age-related impairments. R&I can support people, communities, and policymakers in developing technologically and/or socially innovative services, policies, guidelines and digital solutions for health promotion, disease prevention and (re)habilitation in ways that are accessible, equitable, and effective. R&I can also provide new evidence, methodologies and tools to increase health and digital health literacy, encourage healthy behaviour, and empower individuals across all age groups to manage their own health. Key to delivering on this expected impact is the availability and accessibility of real-world health data, which will require appropriate use and governance of existing and emerging data resources (e.g. European Health Data Space, research and data infrastructures). R&I activities will contribute to the European care strategy[70] and the digital transformation of health and care in the EU[71].

69. Proposal for a Regulation laying down Union procedures for the authorisation and supervision of medicinal products for human use and establishing rules governing the European Medicines Agency, COM(2023) 193 , 2023/0131(COD), 26.4.2023
70. Communication from the European Commission on the European care strategy, COM(2022) 440, 7.9.2022.
71. Communication from the European Commission on enabling the digital transformation of health and care in the Digital Single Market; empowering citizens and building a healthier society, COM(2018) 233, 25.4.2018.

2. Living and working in a health-promoting environment

The expected impact is that people's living and working environments are health-promoting and sustainable thanks to a better understanding of the environmental, occupational, social, sex and gender-related, and economic determinants of health.

Research and innovation will produce new evidence, methodologies, and technologically and/or socially innovative tools to understand, identify and assess the risks and benefits of these determinants for human health, and to enable inclusive policy actions to promote health and prevent disease. Results will support the EU's overarching policy frameworks such as the European Health Union and its EU Global Health Strategy, the EU non-communicable diseases initiative, the EU strategic framework on health and safety at work and the European Green Deal and related policy initiatives, including the chemical strategy for sustainability, the zero-pollution action plan, the 8th Environment Action Programme, the EU biodiversity strategy and the EU policy on climate adaptation and resilience. The outcome will also contribute to the development of new and improved public health actions (considering a One Health approach when relevant) and help foster health-promoting behaviour in living and working environments. To achieve sustainable impacts, R&I must follow a 'health in all policies' approach, providing evidence and stimulating its uptake into policies at EU, national, regional and local levels. Research and innovation should also consider today's major environmental challenges such as the triple planetary crisis concerning the intertwining of pollution, climate change and biodiversity loss, as well as climate-related environmental hazards (e.g. floods and droughts) and their impacts on health. It should also consider the benefits of healthy environments for human health and well-being. Strong collaboration across sectors, including with other Horizon Europe clusters and EU Missions, will be needed to secure the best possible outcomes for society. Cross-sectoral collaboration will also help empower citizens to place environmentally friendly options at the centre of their decision-making and to adopt health-promoting behaviour. International cooperation, for example with the European Environment and Health Process, and synergies between Horizon Europe projects and partnerships working in similar areas, including at science-policy level, will drive forward research and innovation to deliver on this expected impact.

3. Tackling diseases and reducing disease burden

The expected impact is that healthcare providers improve their ability to tackle and manage diseases (infectious diseases, including poverty-related and neglected diseases, non-communicable and rare diseases) thereby reducing the disease burden on patients and enabling healthcare systems to perform more effectively. It can be achieved through better understanding, prevention, diagnostics, treatment, management, and cure of diseases and their co- and multi-morbidities, more effective and innovative health technologies and medical countermeasures, better ability and preparedness to manage pandemic and/or epidemic outbreaks, and improved patient safety,

There is a need to continue supporting research and innovation to provide new or improved prevention and preparedness measures, early diagnosis and screening, public health interventions, diagnostics, pharmacological and non-pharmacological therapies (including

new vaccines, antimicrobials and their alternatives) and (re)habilitation approaches. All these new approaches and measures should create tangible impacts, considering sex and/or gender differences and health equity-related issues, patient safety, and health and digital literacy (including overcoming vaccine hesitancy). International cooperation is indispensable to rapidly advance research and innovation by pulling together the best expertise and know-how available worldwide, to access world-class resources and research infrastructures, and to leverage a critical scale of investment on priority needs through better alignment with other funders of international health R&I. The strengthening of international partnerships and cooperation with international organisations is particularly needed to respond to major unmet needs for global health security and patient safety, including transborder aspects of emerging epidemics and pandemics and the global burden of chronic diseases. Partnering with international organisations will also accelerate the understanding of brain health.

4. Ensuring equal access to innovative, sustainable, and high-quality healthcare

The expected impact is that healthcare systems provide equal access to innovative, sustainable and high-quality healthcare thanks to the development and uptake of safe, cost-effective and people-centred solutions. This is to be accompanied by management models focusing on population health, health systems resilience, and health equity and patient safety, and also improved evidence-informed health policies.

R&I activities are needed to support the development of technologically and/or socially innovative solutions for healthcare systems in all their various dimensions (e.g. reform and policymaking, governance and financing, resilience to and preparedness for health emergencies and climate change, healthcare workforce recruitment, skills, retention and well-being, health service provision and sustainability, interaction with patients, and patient empowerment). In addition, research and innovation can provide decision-makers with new evidence, methods and tools to successfully implement those innovative solutions into their healthcare systems, and to do so equitably and inclusively. Research and innovation can help deliver solutions that are scalable and transferable between different types of healthcare systems in different national, regional and local contexts. It can also provide knowledge that supports the transfer of solutions between countries including on measures to address health inequalities. In turn, this will help improve the governance, resilience and integration of healthcare systems, and the allocation of resources matching people's needs and preferences in a sustainable way that enables needs to be met also in the long term. Sustainability includes not only social and fiscal aspects but also environmental and climate sustainability, making sure the health sector reduces its carbon footprint and supports sustainable use of resources. R&I activities will contribute to among other things the European care strategy, the digital transformation of health and care in the EU, the EU digital strategy, the EU strategy on adaptation to climate change and the European Green Deal.

5. Developing and using new tools, technologies, and digital solutions for a healthy society

The expected impact is that health technologies, data, new tools, and digital solutions are applied effectively thanks to their inclusive, ethically sound, secure and sustainable delivery, integration and deployment in health policies and in health and care systems.

Support for R &I is needed on the large spectrum of tools and technologies for biomedical research, prevention, diagnosis, therapy and health monitoring. This includes enabling technologies not least innovative biotechnological approaches. The emergence of the European Health Data Space will create an additional boost to cross-border, data-driven approaches and innovation, e.g. for personalised medicine or patient safety. High-quality health data (incl. real world data) combined with digital technologies, modelling, and AI tools, such as advanced human digital twin solutions, have a high potential for advancing R&I that supports healthcare systems and pandemic preparedness and response. It is paramount that these data driven approaches and technologies are inclusive and consider gender differences as well as various user needs. To boost the development and acceptance of new technologies and implement them successfully and responsibly into health policies and health and care systems, it will be essential to anticipate the regulatory and market access challenges that they may face and manage their benefits and risks. This involves careful consideration of safety, effectiveness, interoperability, appropriateness, accessibility, comparative value added, and sustainability (environmental, fiscal, and socio-economic) as well as ethical, societal, regulatory, and legal issues. The development and uptake of new technologies for high-quality healthcare, increasingly based on personalised approaches, will need to draw on multiple disciplines and require cross-sectoral cooperation among all those concerned, including end-users (patients, healthcare providers and workforce, researchers, regulatory bodies, policymakers, and funders). These interactions will help address unmet needs via integrated tools, hybrid health technologies and digital solutions (including those with limited commercial interest). It will also support the design and development of health products and services tailored to the needs of specific population groups, thereby improving patient outcomes and reducing health inequalities.

6. Maintaining an innovative, sustainable, and competitive EU health industry

The expected impact is that the EU health industry is innovative, sustainable, and globally competitive thanks to improved uptake of breakthrough technologies and innovations (including social innovations) that make the EU with its Member States and Associated Countries more resilient and less reliant on imports of critical health technologies.

There is a need to further support cross-sectoral R&I and the convergence of health technologies (integrating medical technologies, pharmaceuticals, biotechnologies, digital health, and e-health technologies) to strengthen the single market. R&I is needed to help implement the digital single market strategy and the pharmaceutical strategy for Europe, and to support standardisation and demand-driven innovation. Providing evidence and guidelines for stakeholders, policymakers and regulators will also help stimulate the take-up of innovations that contribute to sustainability (environmental, fiscal and socio-economic)

and the European Green Deal objectives, while strengthening access to healthcare for all and reducing health inequalities.

The health sector is subject to strict regulatory requirements that impose the demonstration of safety and clinical benefits. This means additional development steps, uncertainties, and a longer time to market. Therefore, it remains important to ensure continued support to studies for health assessment procedures, clinical performance demonstration, quality assurance schemes and standardisation. Research and innovation are also still needed to develop new cross-sectoral business models that enable health-related industries to cooperate early with healthcare systems in the development of value-added products and services for effective uptake and deployment of innovative solutions. Such solutions should deliver on the triple aim of improving the patient experience of care (including safety, quality, equity and satisfaction), improving the health of populations, and reducing the per capita cost of healthcare. Furthermore, when there is an unmet need and a market failure, incentives and support will be considered to promote the demand of innovative goods and services and to foster the uptake of innovation in health systems.

Table 1 . Overview of expected impacts, intervention areas, and partnerships

EXPECTED IMPACT	INTERVENTION AREAS COVERED	EUROPEAN PARTNERSHIPS
1. Staying healthy in a rapidly changing society	1.2.1. Health throughout the life course 1.2.2. Environmental and social health determinants	
2. Living and working in a health-promoting environment	1.2.2. Environmental and social health determinants 1.2.1. Health throughout the Life Course	Partnership on risk assessment of chemicals
3. Tackling diseases and reducing disease burden	1.2.3. Non-communicable and rare diseases 1.2.4. Infectious diseases, including poverty-related and neglected diseases	Rare diseases One Health antimicrobial resistance Fostering a European research area for health research Pandemic preparedness Brain Health
4. Ensuring equal access to innovative, sustainable and high-quality healthcare	1.2.6. Healthcare systems	Transforming health and care systems
5. Developing and using new tools, technologies and digital solutions for a healthy society	1.2.5. Tools, technologies and digital solutions for health and care, including personalised medicine	Personalised medicine

6. Maintaining an innovative, sustainable and competitive health industry in Europe	1.2.5. Tools, technologies and digital solutions for health and care, including personalised medicine 1.2.6. Healthcare systems

In the table, partnerships are indicated for one impact even if some of them contribute to several impacts.

INTERNATIONAL COOPERATION

International cooperation is a natural component of health research and innovation. Over recent decades, the EU has established solid links with non-EU countries and international organisations primarily via global multilateral initiatives.

Recent examples demonstrate the ever-growing need for a global response to increasing health challenges: cross-border health threats such as the recent COVID-19 pandemic; the spread of antimicrobial resistance; environmental factors in an urban or rural context creating similar exposure and occurrences in different regions of the world; the health impacts of climate change, biodiversity loss and pollution; and the impacts of Russia's war of aggression against Ukraine and of the displacement of war-affected people on all aspects of health.

With the EU Global Health Strategy, the EU seeks to regain lost ground to reach the universal health-related targets under the United Nations 2030 Sustainable Development Goals. Horizon Europe's Health Cluster will remain an essential vehicle for executing the EU's international commitments on global health, notably Sustainable Development Goal 3 (SDG 3) on health and well-being for all, the objectives and targets of World Health Organization (WHO) action plans and programmes, and the dialogue on health themes within international fora such as G7, G20 and with other global partners. In the context of global health, the Health Cluster's ability to react swiftly and decisively to public health emergencies remains of utmost importance.

Seeking synergies with the EU's external cooperation and humanitarian policies and programmes will not only deepen the links between health research and its implementation. It will also amplify the uptake and deployment of R&I results and solutions across the globe and thus the impact of EU investment. International actions of the Health Cluster will be in line with the EU's Global Approach to Research and Innovation and the EU Global Health Strategy (2022).

In the framework of global health, the main areas of cooperation with the World Health Organization, other international organisations and bodies, and low and middle-income countries are set out below.

- **Infectious diseases and antimicrobial resistanc**e, and poverty-related and neglected infectious diseases through the Global Health EDCTP3 Joint Undertaking, which is the third programme of the European and Developing Countries Clinical Trials Partnership (EDCTP). It aims to accelerate the clinical development of new or improved health technology products in sub-Saharan Africa. Global Health EDCTP3 also aims to address antimicrobial resistance in sub-Saharan Africa, taking into consideration the specific environmental and epidemiological factors that influence the spread of antimicrobial resistance in this region. A dedicated Horizon Europe partnership on One Health antimicrobial resistance will specifically address antimicrobial resistance with a One Health approach, by coordinating and aligning activities and funding between the Commission and countries in the EU and beyond.
- **Preparedness and quick response to public health emergencies** supporting the action of the European Health Emergency Preparedness and Response Authority (HERA) through dedicated partnerships, such as the Horizon Europe pandemic preparedness partnership, and multilateral initiatives, such as the Coalition for Epidemic Preparedness Innovations (CEPI) or the Global Research Collaboration for Infectious Disease Preparedness (GloPID-R).
- **Chronic diseases**, through dedicated actions and multilateral initiatives, such as the Global Alliance for Chronic Diseases (GACD) and the International Rare Diseases Research Consortium (IRDiRC) or the European Partnership on Rare Diseases open to non-EU countries.
- **Personalised medicine**, through dedicated actions and multilateral initiatives, such as the International Consortium for Personalised Medicine (ICPerMed) and linked regional activities such as the EU-Africa PerMed initiative between the EU and African countries, the European Partnership on Personalised Medicine (open to non-EU countries)) or the International Human Epigenome Consortium (IHEC).
- **Cohort-based clinical studies of health and diseases**, through common approaches and protocols. Impact of the environment on human health, through dedicated actions on the exposome and through cooperation with the WHO European Environment and Health Process.
- **The Latin America and Caribbean initiative**: the Health Cluster will contribute to deepening EU relations with the region of Latin America and the Caribbean (LAC) as part of the LAC initiative under Horizon Europe 2025-2027.
- **The Human Frontier Science Programme**: through a dedicated support to this prestigious international programme funding frontier life science research.

US participants in projects funded under the Health Cluster will continue to be eligible for funding, in recognition of the openness of the USA National Institutes of Health (NIH) programme to European researchers.

Synergies with other EU funding programmes

Developing strong synergies between the Health Cluster and other EU programmes is key to maximising the impact on public health. Synergies can enable more effective and efficient use of resources and improve coordination and cooperation between stakeholders in the field of health. Under the present strategic plan, synergies will in particular be developed between Cluster 1 and the EU4Health and Digital Europe programmes. Synergies will also be sought with the ERDF and ESF+ programmes and with other EU funding programmes where relevant (e.g. the Euratom Research and Training Programme).

Synergies with EU4Health: sequential synergies will be developed between Horizon Europe and EU4Health to facilitate the uptake, further development and deployment of new knowledge and technologies, primarily in the fields of **cancer, non-communicable diseases, mental health, pandemic preparedness and antimicrobial resistance from a One Health perspective, health systems and digital health**. Sequential use of R&I results can for example be considered in the context of future joint actions in EU4Health or for further real-life piloting and consolidation of evidence for policymakers and other stakeholders. As regards **pandemic preparedness**, Horizon Europe funding in recent years was devoted to research on pathogens with high pandemic potential. This research was complemented by various actions under EU4Health to speed up the development of and access to medical countermeasures for epidemic and pandemic preparedness. To further strengthen the synergies between Horizon Europe and EU4Health in the coming years, a sequential approach to the development of medical countermeasures could be developed and supported at different stages across both programmes. To support the development of the European Health Data Space, results from Horizon Europe projects on cross-border data use should feed into EU4health actions developing the European Health Data Space infrastructure in Member States and cross-border.

With complementary funding and activities from Horizon Europe and EU4Health respectively, the Health Cluster, the **Horizon Europe Mission on Cancer** and **Europe's Beating Cancer Plan** have been working in concert since the beginning of the first strategic plan (2021-2023) to reach their common goals set throughout the whole cancer care continuum. This synergistic approach is expected to continue under the second strategic plan.

Synergies with the Digital Europe Programme: sequential synergies will also be developed between Cluster 1 and the Digital Europe Programme. This will help secure the establishment and roll-out of digital, privacy-preserving (distributed) data infrastructures and high-performance computing resources, and the development of methods and tools for modelling complex phenomena related to human health; these will leverage and build upon the results of Horizon Europe research and innovation actions. In addition, Horizon Europe actions directly support the achievement of the objectives under the Digital Decade programme by improving interoperability within the European Health Data Space and access to health records.

Synergies with the ERDF: synergies achieved through the **co-funding of actions** by different EU programmes should also be explored under the second strategic plan. The draft Commission notice on synergies between Horizon Europe and ERDF[72] gives guidance on how to use funding from the ERDF programmes available at national/regional levels to co-fund European Partnerships launched under the Health Cluster.

3. Cross-cluster Complementarities

Table 2 Overview of Cross Cluster Complementarities

RELEVANT CLUSTER	POSSIBLE COMPLEMENTARITIES
2. CULTURE, CREATIVITY AND INCLUSIVE SOCIETY	Social inclusion and health equity (gender equality, vulnerable or marginalised groups), promotion of healthy behaviour and health literacy. Mental health promotion and prevention, treatment of mental health issues and destigmatisation of mental illness. The long-term sustainability of public health systems (via for example economic and organisational models and measures for cost effectiveness and fiscal sustainability). The resilience of healthcare systems in relation to, for example, demographic change, migration, climate change, pollution, emerging epidemics, and antimicrobial resistance.
3. CIVIL SECURITY FOR SOCIETY	Health security and emergencies, including preparedness and response to epidemic outbreaks/pandemics, and bioterrorism. Security and resilience of healthcare infrastructures, including digital health infrastructures.
4. DIGITAL, INDUSTRY AND SPACE	Biotechnology approaches, artificial intelligence, digital twins, data-driven approaches for personalised disease prediction, prevention and treatment Digitalisation of the health sector, including medical technologies, imaging, e-health and telemedicine. Regulatory science and standards for health and care technologies and tools. Cybersecurity of (public) health systems, products and infrastructures of digitalised health and care.
5. CLIMATE, ENERGY AND MOBILITY	Surveillance, prediction and mitigation of the health impacts and risks of climate change. Preventable environmental causes of diseases including transport and combustion-related environmental pollution. Health impact assessment, for example of exposure to environmental stressors including pollution. Reduction of the healthcare sector's carbon footprint and its sustainable use of resources.

72. Commission Notice on synergies between Horizon Europe and ERDF programmes (O.J. C421/7 of 4.11.2022).

6. FOOD, BIOECONOMY, NATURAL RESOURCES, AGRICULTURE AND ENVIRONMENT	Role of nutrition for healthy lives (including human microbiome, malnutrition and over-nutrition, safe food). Personalised diets (including food habits in general and childhood obesity in particular). Impact of food-related environmental stressors on human health Health impact assessment (e.g. of water, soil and air pollution, and biodiversity loss). Preventable environmental causes of diseases. Health security, One Health approach across human, animal/plant, soil/water health.

CLUSTER IMPACT SUMMARY

Cluster 2

CULTURE, CREATIVITY & INCLUSIVE SOCIETY

The broad research and innovation objectives and the research destinations set out in the 2021-2024 strategic plan for Cluster 2 'Culture, Creativity and Inclusive Society' remain pertinent for the period 2025-2027. This continuity ensures a stable and predictable funding environment for policy-oriented, interdisciplinary, European collaborative research involving social sciences and humanities, including the arts. However, this strategic plan needs to consider the challenges that have put the resilience of European societies and the world under pressure.

As such, activities in Cluster 2 will continue to focus on challenges pertaining to democratic governance, inclusiveness, cultural heritage and the creative economy, and on ensuring just and fair green and digital transitions. Russia's war of aggression against Ukraine, a European neighbourhood and EU candidate country, is already having profound and long-term impacts. The exacerbated conflict in the Middle East has led to polarisation in European society, including an ominous resurgence of antisemitism and other forms of hatred. The impacts of such challenges can be felt not only on societies, economies, geopolitics and international relations, but also on identities, interpretations of history and culture, science policy decisions, and important new research avenues to explore. The current context of complex, mutually reinforcing crises cannot be properly understood without the help of interdisciplinary expertise mobilising social sciences and humanities. Similarly, social acceptance of policy solutions and trust in democratic decision-making cannot be achieved without citizen engagement and inclusive education, training and cultural participation.

All these global challenges are interconnected, whether they are geopolitical, or relate to the public health, energy, climate or digital transformations, changes in the nature of democratic systems and political landscapes, migration, or the profound reconfigurations of global markets, value chains and the realms of work and productivity. Addressing the concerns and expectations of the European public in that respect goes far beyond technological innovation and technocratic solutions: it is a major issue of political participation, social justice, economic fairness and of environmental and cultural sustainability.

This is why the extensive mobilisation of multi-, inter- and transdisciplinary research involving social sciences and humanities, including the arts, is at the core of the 2025-2027 strategic plan. International comparison and cooperation will gain further attention in the cluster work programmes for the period 2025-2027. The regional and local dimension of policies in the field of governance, cultural heritage and inclusiveness may be further explored.

First, research and innovation actions in the cluster will address knowledge gaps and policy needs concerning the impact of the armed conflicts, resource scarcity, technological change, and geopolitical tensions on the health of European democracies. Investments will help foster more resilient European democracies better prepared to withstand threats, both external and internal. They will also contribute to designing innovative ways to update Europe's democratic systems to make them more inclusive, transparent, accountable and representative of the people.

Second, research and innovation at the intersection between technology, the arts, and access to culture will explore the means to boost the societal value of tangible and intangible cultural heritage. The innovation potential of the cultural and creative sectors and industries will be supported by, for instance, sectoral analysis and ecosystem approaches, practice-, arts-, and performance-based research. The multidimensional nature of cultural heritage will be explored and developed in the context of the green and digital transitions.

Third, research will help to understand and thus resolve forms of inequalities in addition to income inequality or gender inequality, such as territorial (rural-urban divide) and environmental inequality, and well-being and health inequality (including mental health). Furthermore, research under this cluster will investigate the contribution of both European and national cohesion, regional, urban and rural development policies to sustainable fair, green and digital transitions. It will also consider the impacts of demographic changes, migration, ageing, and diversity.

In addition, an important strategic innovation is the establishment of two new European Partnerships co-funded with national authorities: 'Social Transformations and Resilience' and 'Resilient Cultural Heritage'. They will strengthen the alignment of national and European research and innovation policies and funding.

HOW WILL CLUSTER 2 MAKE A DIFFERENCE?

Cluster 2 will programme investment to achieve the following four expected impacts.

Expected Impacts

7. Reinvigorating democratic governance

The impact means that democratic governance is reinvigorated by improving the accountability, transparency, effectiveness and trustworthiness of institutions and policies based on rule of law, and through the expansion of active and inclusive citizenship empowered by the safeguarding of fundamental rights.

The aim of the research investment supporting this impact is to develop a robust evidence base on which to form effective, relevant and sensitive policies that bolster the resilience of democratic systems and protect them from threats. R&I actions will aim to increase the capacity of researchers and policy makers to better understand geopolitical shifts and shape the EU's role in the world. Part of this effort will include promoting human rights globally and ensuring peace in Europe, contributing thus to internal and external EU policies that allow/ensure respect for citizens' fundamental freedoms (with particular attention to neighbourhood countries). In this context, and in light of the conflicts in Ukraine and the Middle East, activities will measure and evaluate the impact of wars and post-conflict reconstruction on governance

at all levels, together with improving understanding of the origins, dynamics, prevention and resolution of conflicts. In addition, the research will encompass the protection of democracy from external and internal threats, including foreign interference and manipulation of information, disinformation and other forms of hybrid threats, together with an analysis of the effectiveness of science diplomacy as a way to strengthen multilateral cooperation.

The expected impact of the funded projects also includes reaching a deeper understanding of radicalisation processes and the risk of violent extremism, especially if conveyed by political motivation and populist movements, to effectively limit its most extreme and violent expressions through participation and inclusion. Part of the research will encompass understanding the transformation of politics and the evolving landscape of representative democracy, including the role played by national elites, polarisation and socio-cultural tensions between majority and minority populations. Funded actions will aim to support the creation of a European research hub on contemporary antisemitism and Jewish life and culture[73], and will also seek to deepen understanding of hatred, identifying its drivers and ways to address it. The projects will also aim to improve education for democratic citizenship, focusing especially on educating young people to participate in democratic governance, and involving them in decision-making processes. The challenges to democracy that will be investigated are also those posed by digital transformation: the impact is to improve the understanding of emerging technologies (such as artificial intelligence, big data, and the metaverse) and their impact on policymaking, public service delivery and governance. Activities can thus contribute to the effectiveness of public administrations and services. Those will include the judicial system whose efficiency and independence could be assessed and enhanced through the funded R&I actions.

As in the rest of Horizon Europe, the gender dimension of these issues will have to be considered, and intersectional approaches will be encouraged. Cultural, philosophical and historical perspectives, in combination with theoretical rigour, experimentation and normative reflection, will set the framework for soundly understanding present developments and help to map future pathways. In the medium to long term, the knowledge, data, and scientifically robust recommendations and innovations generated will enhance decision-making on all aspects relevant to democratic governance.

8. Realising the full potential of cultural heritage, arts and cultural and creative sectors

The expected impact implies that the full potential of cultural heritage, arts and cultural and creative industries and sectors as drivers of both sustainable innovation and a European sense of belonging is realised through a continuous engagement with society, the general public, and economic sectors.

The research and innovation actions contributing to this expected impact will pursue three

73. Joint Communication to the European Parliament and the Council: No place for hate: a Europe united against hatred (JOIN(2023) 51)

priorities: green, digital and innovative. These priorities will be interpreted in a broad way to allow R&I actions funded under this destination to develop ground-breaking solutions that open up new perspectives and dimensions for the future.

R&I actions will help develop a shared European sense of belonging and a European identity based on the European cultural heritage. Investments will aim to widen the understanding of and engagement with cultural heritage. An important objective will be to strengthen the role of cultural heritage and cultural and creative industries and sectors in supporting prosperous and environmentally, socially and culturally sustainable and resilient societies.

Therefore, R&I actions will aim to reinforce the innovation potential of cultural heritage and cultural and creative industries and sectors, as well as their contributions to the economy and competitiveness. A special focus will be put on fostering a culture- and creativity-driven European innovation ecosystem, with cultural heritage and cultural and creative industries and sectors at its heart. Research and innovation actions will be developed both holistically and on specific sectors or issues.

Research and innovation results are also expected to contribute to European integration, social inclusion and to societal and territorial cohesion by focusing on better, wider and more equal access to tangible and intangible cultural heritage, and their connections to natural heritage. Research and innovation activities will focus on analysing the impact of climate change on cultural heritage and exploring the contribution of cultural heritage and related activities to green and sustainable development and its social acceptance.

Future deployment of technological advances in fields such as artificial intelligence and other technologies will have far-reaching impacts on culture, well-being and living heritage, such as skills, values and beliefs. Research and innovation investment will help build the capacity to steer the development and anticipate the consequences of such technological advances.

Research and innovation actions will continue supporting the implementation of the European Collaborative Cloud for Cultural Heritage. This is expected to help improve collaboration between European cultural heritage institutions and networks and support high-quality acquisition, management and curation of digitised and born digital heritage assets.

In addition, research may further explore sustainable and inclusive cultural tourism in the EU, such as for instance tourism for people with disabilities, youth, silver age tourism, or tourism related to dissonant heritage. Research might also address the management of heritage sites and collections, assets' provenance, and restitution issues. The destination may also continue its support for endangered languages and the New European Bauhaus Facility.

9. Strengthening social and economic resilience and sustainability

This expected impact focuses on enhancing social and economic resilience and sustainability. This involves gaining a deeper understanding of the multifaceted impacts of various drivers of change, such as technological advancements, global trade patterns, climate change, shifting demographics, and mobility and migration trends. It also emphasizes the interconnectedness of these drivers.

Demographic shifts, rapid technological advancements, alterations in global trade dynamics, the effects of climate change, environmental pollution, geopolitical tensions, and migration pressures are all ushering in profound transformations in European societies and economies. Despite challenges posed by various socio-political factors, it is imperative that we strengthen resilience and sustainability within the EU. These transformations, although accompanied by uncertainties and disruptions, also present opportunities for a new direction in growth and innovation. They underscore the urgent need for forward-thinking policies that foster social cohesion and sustainable economic development.

These changes ripple across society and the economy, impacting the future of work, productivity, demography, migration, asylum, and mobility governance. Understanding the importance of existing and emerging inequalities is critical to strengthen social justice and resilience in European societies. This also requires the effective integration of refugees, migrants and people with migration background into European labour markets and societies.

The research and innovation investment under this expected impact will: (i) improve the understanding of how the ongoing changes impact society; and (ii) inform policy makers on how to mitigate negative externalities and harness newly created opportunities. It will improve the understanding of the interplay between different drivers of change and their social, ethical, political, and economic implications. The improved understanding of the current challenges and their economic, social, and distributional impacts not only will fill in the research gaps but will also inform the design and assessment of policies addressing existing and emerging challenges, including in the area of well-being and particularly in mental health. Overall, the Cluster's activities will help promote the EU's inclusive growth, resilience, and fair transition towards climate neutrality, in line with the European Pillar of Social Rights and its Action Plan, the European Education Area, the EU's policies on jobs and development, and the Just Transition Mechanism.

10. Boosting inclusive growth and reducing vulnerabilities effectively

This expected impact revolves around fostering inclusive growth and effectively reducing vulnerabilities through evidence-based policymaking. These policies are designed to safeguard and enhance employment, skills, education, well-being, social equity, and address various forms of inequality.

In the dynamic landscape of Europe, we are committed to fostering inclusive growth. This includes addressing vulnerabilities that have been amplified by events such as the COVID-19 pandemic and geopolitical tensions. To achieve these goals, we emphasise substantial social investment, including re- and upskilling of the workforce development and innovative policies that can effectively navigate the complexities of the changing landscape.

The implications of these ongoing changes are far-reaching, affecting various aspects of society and the economy, including the education, training, welfare and well-being, public finances, and taxation systems. To address these changes effectively, it is vital to not only understand existing and emerging inequalities, including gender disparities and distributional impacts, but also to prioritise social justice and resilience within the context of green and digital transitions. Furthermore, gaining a better understanding of long-term trends and investment requirements in employment, skills, education, training, and lifelong learning is essential for crafting innovative policies that promote social inclusion and ensure a fair transition.

Research and innovation investment is geared towards deepening the understanding of how ongoing changes impact society, with a specific emphasis on the key objectives of boosting inclusive growth and effectively reducing vulnerabilities. This knowledge will provide valuable insights to policymakers to design and assess policies that effectively address vulnerabilities while capitalizing on emerging opportunities.

Expected impact Intervention areas covered European Partnerships

Table 3 Overview of R&I expected impacts, cluster intervention areas, and Horizon Europe partnerships

EXPECTED IMPACT	INTERVENTION AREAS COVERED	EUROPEAN PARTNERSHIPS
7. Reinvigorating democratic governance	Democracy and Governance	
8.Realising the full potential of cultural heritage, arts and cultural and creative sectors	Culture, cultural heritage and creativity	Resilient Cultural Heritage
9. Strengthening social and economic resilience and sustainability	Social and economic transformations	Social Transformations and Resilience
10. Boosting inclusive growth and reducing vulnerabilities effectively	Social and economic transformations	

In the table, partnerships are indicated for one impact even if some of them contribute to several impacts.

INTERNATIONAL COOPERATION

The intervention areas under Cluster 2 will benefit from insights and perspectives from international cooperation, in line with the EU's Global Approach to Research and Innovation. Engaging in international cooperation will make possible a better assessment of challenges in their global, regional or local context. To this end, work with international partners will be undertaken on issues such as multilateral governance, employment and social aspects of changing trade patterns and value chains, the drivers and governance of migration, the democratic governance of cultural diversity, and the crises and promotion of democracy in the EU neighbourhood. International collaboration will also lead to broader connections when addressing global trends in democratic governance, post-colonialism, intercultural relations and cooperation on cultural heritage, inclusive growth, and decent work and fair working conditions in the context of globalisation. This may include strategic areas of mutual benefit in the context of the new EU-Latin America and the Caribbean initiative under preparation, and the AU-EU Innovation Agenda.

Synergies with other EU funding programmes

The Horizon Europe cluster on Culture, Creativity and Inclusive Society will aim at promoting various types of synergies with other EU programmes, among which the following.

- **Citizens, Equality, Rights and Values Programme**: Sequential and programming synergies to facilitate the uptake of research results by practitioners and reinforcing research actions with civil society actions on the ground.
- **Digital Europe Programme**: There is potential for funding, programming and sequential synergies that support the wide uptake and deployment of innovative digital solutions in areas of public interest (including public administration, justice, health and education), by setting up and making accessible Europe-wide data spaces and platforms and providing SMEs and public administrations access to the latest digital technologies, for example via digital innovation hubs.
- Potential for sequential synergies with **Global Europe**, which supports and consolidates democracy, rule of law and human rights, supports civil society organisations outside the EU, further stability and peace, and addresses other global challenges including migration and mobility.
- **Creative Europe**: Potential for fostering programming synergies that can reinforce the capacity of both programmes to facilitate mutually supportive actions for experimentation, development and implementation of greening practices in cultural and creative sectors, linked to their needs and potential contribution to the green transition and in the context of the energy crisis.
- Synergies with the **European Social Fund Plus (ESF+)** also have a great potential for helping promote the EU's inclusive development, resilience, and fair transition towards climate neutrality, in line with a strong policy framework, under the **European Pillar of Social Rights**, and for the benefit of all people in the EU, especially the most vulnerable.

By supporting EU policy implementation and national structural reforms in the areas of employment, education and skills, and social inclusion, the ESF+ contributes to Member State efforts to reduce unemployment, advance quality and equal opportunities in education and training, and improve social inclusion and integration. Programming synergies with the ESF+ have a potential for fostering social integration of people at risk of poverty and social exclusion, supporting equal access to quality education and training (including through upskilling and reskilling and lifelong learning for all), and boosting the modernisation of labour market institutions and services, aiming to support workers, enterprises and entrepreneurs in adapting to change. Sequential synergies could then be encouraged at a further stage, following the ESF+ implementation on the ground (shared management).

- With EU programmes such as **Erasmus+, European Solidarity Corps** and **DiscoverEU**, there is potential for fostering synergies to promote the integration of cultural heritage, creativity and innovation in the learning, training, volunteering and civic engagement activities of young people across Europe and to foster social cohesion and cross-cultural understanding.
- There is also potential for synergies with EU programmes such as the **Asylum, Migration and Integration Fund (AMIF)**, the **European Regional Development Fund (ERDF)**, the **European Agricultural Fund for Rural Development (EAFRD)** and the **Neighbourhood, Development and International Cooperation Instrument – Global Europe (NDICI – Global Europe)** to support actions related to the integration of migrants into the labour market by supporting their skills recognition and development, and to contribute to efforts to address new challenges of migration in relation to climate change.
- Synergies with the **Neighbourhood, Development and International Cooperation Instrument – Global Europe instrument for the Southern and Eastern Neighbourhood** and the **Instrument for Pre-Accession** which finance actions aimed specifically at increasing the skills of civil society organisations, fact checkers and decision makers, but also at aligning enlargement countries' legal frameworks to the current EU acquis.
- With the **Single Market Programme** and its SMEs pilar there is potential for fostering synergies to promote and strengthen innovation as key element of competitiveness of enterprises in the cultural and creative industries and sectors as well as contributing to their green and digital transition through business-related research actions.
- Synergies with the EU programme '**Inclusive Societies in LAC**', announced by the Commissioner for International Partnerships at the high-level opening of the EU-LAC Forum on 13 July 2023. This contribution represented a key milestone to signal EU commitment with social cohesion in LAC and gave a new impulse to the Team Europe Initiative focusing on education, social cohesion and fighting inequalities. (Implementation process started).

Cross-cluster complementarities

Table 4 Overview of Cross Cluster Complementarities

RELEVANT CLUSTER	POSSIBLE COMPLEMENTARITIES
1. HEALTH	Access to high-quality, fair and inclusive healthcare Social and cultural aspects of mental health Combating socio-economic and gender inequalities Health economics and economics models Adaptation of public health systems to so challenges (e.g. migration, demographic change, access to health by marginalised and vulnerable groups)
3. CIVIL SECURITY FOR SOCIETY	Countering radicalisation and extremism Protecting fundamental rights and civil liberties Combating disinformation and fake news Tackling irregular migration and safeguarding the rights of migrants, including refugees and asylum seekers, in line with the EU Charter of Fundamental Rights Protecting cultural heritage
4. DIGITAL, INDUSTRY, SPACE	Research on the nature of job transformations for industry 4.0/5.0 and its role in transitioning to a sustainable, human-centric and resilient Europe Foster technological progress to empower society and make it more sustainable, social and economic Analysis of digital ecosystems in creative and cultural industries Cross-cutting analysis of business models for sustainable development Study of participation of the general public and public engagement in industrial technologies Respect of citizens' rights and freedoms in the use of digital technologies Changes in the model of work and the effect on human behaviour Ensuring meaningful and effective ways of gaining the participation and trust of vulnerable groups

5. CLIMATE, ENERGY AND MOBILITY	Social sciences and humanities research can provide analysis and recommendations for a just green transition and how to ensure the public's engagement and participation, considering socio-economic vulnerabilities, inequalities, and potential risks Social sciences and humanities R&I input to development of learning for sustainability Bridging climate adaptation and cultural heritage safeguarding Active involvement of the general public in the transition towards a society that is both resilient to climate challenges and carbon-neutral Research on migration in relation to climate change and pollution and on gender-differentiated impacts of climate change Inclusive, community-led approaches that strengthen participation, democratic governance and climate resilience Impact of climate change on cultural heritage
6. FOOD, BIOECONOMY, NATURAL RESOURCES, AGRICULTURE AND ENVIRONMENT	Knowledge gaps, integrated policies and place-based innovations considering the specific needs of rural communities Inclusive and innovative forms of participation Advancement of socio-economic conditions in rural and coastal regions Knowledge of the relationship between culture and food habits Behavioural change and new forms of production and consumption

CLUSTER IMPACT SUMMARY

Cluster 3

CIVIL SECURITY FOR SOCIETY

Developments since the strategic plan for 2021-2024 focus on the **need for prevention of, preparedness for and resilience to a wide range of threats to internal security, the security of citizens, critical infrastructure and the security of society as a whole**.

The war in Ukraine has made all the more pressing the need for civilian protection and resilience supported by civil security research. Unlike defence research, civil security research aims to strengthen the ability of EU's population and of EU society to prevent, prepare for, and be resilient to a wide range of security threats. The EU needs to improve **its population's protection and resilience, and better equip its critical entities or organisations and infrastructure** against increasingly complex security threats that can exploit the increased interconnectedness of the cyber and physical aspects of life, that can be hybrid, and that can be land threats and/or maritime threats (including underwater and offshore).

Times of crisis are a breeding ground for the emergence of crime. The EU needs to be prepared to face the increasing threat from terrorism and **organised crime**, such as firearms trafficking in the EU due to the armed conflicts in its neighbourhood, and to be able to deal with an increase in drug trafficking and cybercrime, as evidenced after the COVID-19 crisis.

The potential for large-scale **movements of people**, whether as a result of war, or of social/economic/environmental stress, or the instrumentalisation of migration, increasingly requires multi-level situational awareness and border management capabilities. These capabilities need to be effective, but also as little intrusive as possible, and mindful of fundamental rights.

As well as being prepared to face individual threats, the EU needs to be prepared for their increased tendency to arise at the same time (compound events) and/or to trigger a chain of negative effects (cascading events), and to require the coordinated action of a number of security practitioners to deal with them (thereby increasing complexity). Climate scientists report the likelihood of more frequent and **more serious climate-related extreme events**. The EU must also be ready to face other threats, whether accidental or intentional, of human or natural origin – for example, pandemics, earthquakes, industrial accidents (including those that are the result of the workings of nature, or natural hazards that cause technological accidents [Natech]), terrorist attacks, hybrid threats, cybercrime, etc.

Continued **technological development and digitalisation** (such as synthetic biology, AI, immersive technologies, algorithmic manipulation) can create new and unforeseen vulnerabilities and new opportunities for criminals and violent extremists as well as new challenges, needs and opportunities for law enforcement authorities. The more widespread and ubiquitous digital technology is, the greater **cyber threats** may become, putting infrastructures, businesses and individuals at risk. Research on cybercrime and cybersecurity helps to address these matters by developing tools to support law enforcers and prosecutors. Cybersecurity is key for all areas of the economy, and for the European single market. The

recently 'upgraded' cybersecurity legislative framework in the EU (i.e. NIS2 and the proposed Cyber Resilience Act and Cyber Solidarity Act) requires stricter obligations for relevant entities and vendors.

Negative socio-economic trends (such as reductions in real income) and climate adaptation create potential for greater **social instability and mistrust**, which may escalate into conflict or may create opportunities for extremists and malicious actors to spread hate speech and disinformation, in particular online, with associated security implications and that may lead to violent radicalisation. These developments and those referred to above, as well as major events since 2021 (the COVID-19 pandemic, Russia's war of aggression against Ukraine, the conflict in the Middle East, recurring wildfires), and the likelihood of access to basic resources (water, food, energy) being limited, have increased the **security and resilience needs of the general public** since the first strategic plan.

Cluster 3 can make vital contributions to rising to those challenges. In doing so, it will support the EU's **open strategic autonomy**, its **economic security** and the competitiveness of its **civil security industrial base**. Cluster 3 will continue to support the implementation of the EU Security Union Strategy and the sectoral strategies, as well as of legislation and action plans identified under the expected impacts set out below.

HOW WILL CLUSTER 3 MAKE A DIFFERENCE?

The **following horizontal priorities will be developed through work programme action**s, building on security research practice.

- The **active involvement of relevant security practitioners** (first responders, police, border and coast guards, customs authorities, critical infrastructure operators) ensures that research is tailored to their needs and conducive to the subsequent uptake of innovation. Successful deployment of innovation can help authorities meet the challenges of limited availability of workers. Research should also pay attention to strengthening the capacity of competent authorities responsible for addressing the environmental and health impacts of extreme natural events such as floods, earthquakes, or wildfires. Cluster 3 will involve practitioners in defining research needs (so that the expected outcomes of projects actually address operational needs), and will continue to require practitioners' participation in projects whenever necessary.
- A more **holistic**, systemic and cross-cutting research approach to some challenges that involve different communities of practitioners and of researchers, different capabilities, and/or different threats at the same time.
- **Foresight research** (especially under the work programme destination 'Strengthened Security Research and Innovation', see below) to gain insights into possible future emerging threats and the capabilities required to deal with them. This research should

build on the results of the Networks of Practitioners funded under Horizon 2020.

- **Social acceptability, legal and ethical questions** must be at the heart of European security research. Ethics, respect for fundamental rights, including human rights, privacy and the protection of personal data, as well as responsible research, all of which make for better research outcomes, are an added value of European research and innovation activities. They are also the characteristics that make it possible to conceive, design and develop evidence-based civilian security solutions that are as little intrusive as possible and the best at respecting freedoms rights and values. Solutions conceived in this way, by design respecting fundamental rights including privacy, also give EU industry a competitive advantage.
- **European citizens** and companies should be **owners of their own security**, should be aware of risks to it and should have control over how to deal with them. **Participative resilience** is needed, whereby European citizens and companies contribute to the resilience of society and their contribution is acknowledged as such by professionals. This also means including individuals in security research as a form of active citizenship and as a way of improving the quality of results and getting social acceptance and ownership of research solutions. The systematic incorporation of social sciences and humanities (SSH) into security research should be encouraged, and mandatory for certain topics, and particular attention paid to vulnerable groups. In line with the EU Charter of Fundamental Rights and the Commission's 'Union of Equality' priorities, the diversity and gender balance of members of the public involved in security research will be ensured.
- Drawing lessons from recent disasters and conflicts to develop a deeper understanding of **how populations and societies can be safeguarded** from unintended consequences of armed conflicts.
- Better understanding the **causes of potentially destabilising phenomena** such as social unrest, crime, violent radicalisation and disasters.
- Increasing **EU citizens' overall perception of security** by reducing daily/frequent crimes in public spaces. This requires on the one hand enhancing technological detection, and on the other hand increasing overall perceptions of security via e.g. security-by-design approaches. It also requires innovative approaches to measure perceptions of security. The perception of security contributes to regaining the confidence of European citizens in places that have been targets of terrorism.
- Contributing to achieving and improving European **open strategic autonomy** in technologies identified as critical for civil security. This will be done by developing European solutions for the capability needs of European security practitioners, by contributing to an EU industrial policy and by increasing research security.

Cluster 3 will require, where appropriate, that projects:

- do **piloting** in operational environments and that they be **validated** by the practitioners of the developed capability, including over extended periods of time when appropriate;

- dedicate specific work packages to **market uptake and industrialisation** issues, including potential synergies with other EU and national funds;
- assess their solutions in terms of **environmental sustainability**, e.g. AI algorithms that consume less energy;
- develop relevant **education and training** curricula, especially for security practitioners but also for other relevant authorities and for critical infrastructure operators, and that they raise the general public's awareness of security including with educational tools where relevant;
- identify lessons learnt at the end of the project for possible future ones.

The EU also needs to be able to rapidly (re-)deploy research to deal with new threats and to accelerate innovation. Cluster 3 should consider long- and medium-term challenges (at appropriate different stages of technological readiness level) but also allocate budget for fast and focused projects, e.g. projects of no longer than 2 years duration, small consortia, with a maximum budget of EUR 2 million per project and involving SMEs working directly with practitioners. Consideration should also be given to increasing the number of open topics.

Expected impacts

Cluster 3 will programme investment to achieve the four expected impacts set out below in continuity with the strategic plan 2021-2024.

11. Reducing losses from natural, accidental and human-made disasters

Given the increasing frequency and ever greater impacts of disasters resulting from climate extremes, natural, geohazards and human-made hazards, the EU needs to invest more in improving disaster risk management, tools for first responders and societal resilience.

R&I actions under the **destination 'Disaster-Resilient Society for Europe' (DRS)** will have the overarching objective of improving resilience. Actions will continue to explore initiatives and experiments involving the development of technological or methodological solutions for crisis management and support for emergency responders, getting the general public and vulnerable groups more involved and more knowledgeable in this area and improving interactions between local, regional and national authorities, public practitioners, critical infrastructure operators and civil society. New tools or solutions should build on what has been developed in past projects and be capable of being integrated into existing (legacy) systems.

Actions will also focus on multi-service capability developments, in particular tools and technologies to support direct operational needs in case of a disaster. This will be done in a scalable way, covering areas from small rural towns to economically developed ones with a high population density. Capabilities need to be upgraded to match the new resilience stakes and expectations of practitioners and of society as a whole. The EU should learn from past

disaster events by identifying gaps in capabilities that the response to such events showed were lacking.

Cluster 3 will continue to follow a multi-hazard approach, addressing disasters and threats of all kinds: climate-related or natural and geological hazards, industrial accidents, pandemics, intentional hostile acts including terrorism and armed conflict. Particular attention will be paid to floods and wildfires, as well as to chemical, biological, radiological, nuclear and explosive (CBRN-E) threats.

The general public, local communities and voluntary organisations need to be included as active partners in research, the results of which in turn need to empower citizens to act. Research should help citizens to improve their own resilience to crises. Another matter that needs to be addressed is the public's perception of, and involvement in, civil defence in the event of very large-scale disasters including armed conflict.

Research needs to involve local decision-makers and operational responders, i.e. first and second responders, those first in line when a security incident occurs within their premises such as infrastructure operators, local authorities and cities (public services, transport and utilities) as well as the competent authorities responsible for dealing with secondary impacts (environmental, health), and bearing in mind the socio-economic and cultural context. There is a need for greater risk awareness/ preparedness, stronger governance and timely communication of the foreseeable impacts of disasters. Better capabilities could include standardisation inputs, such as standard operating procedures for foresight, risk analysis or guidance on investing/economics in disaster risk management; trusted communication channels; and other technologies resulting from research and innovation initiatives.

Cluster 3 will support the implementation of the EU Disaster Resilience Goals and UN Disaster Risk Reduction policies, involving closer coordination with the Union Civil Protection Knowledge Network, the rescEU civil protection mechanism and Member States' civil protection authorities, as well as an enhanced dialogue at international level with the United Nations Office for Disaster Risk Reduction (UNDRR) on recommendations for the Sendai Framework. Such closer coordination with other programmes will make it possible to further streamline Cluster 3 research programming. For example, Cluster 3 should focus on its core added value, which is a strong operational character for preparedness, response and learning, while maintaining synergies with broader prevention issues such as climate-related risks, covered by Cluster 5, and the Mission on Climate Change Adaptation. There are similar examples of closer coordination with Cluster 6 and the One Health approach, regarding, for instance, threats to water and food security (as a result of intentional degradation or terrorist acts), and impacts on air quality (as a result of wildfires). The annual Knowledge for Action in Prevention and Preparedness (KAPP) calls for proposals, as well as scenario-building initiatives, represent the disaster risk management and civil protection community's latest prioritisation of research needs for the policies outlined above.

From a technological perspective, Cluster 3 will ensure greater involvement of practitioners in close cooperation with the Member States and EU agencies, not only in research development and implementation, but also the identification of gaps and needs and future research topics. Actions to develop tools and technologies to meet operational capability needs should be aimed at higher technological readiness levels (TRLs). Cluster 3 will incentivise the use of EU space programmes' services in this destination where relevant. Finally, it will be important to take into account how research results, both those still to come and those already developed in past projects under the DRS destination, can be turned into deployable solutions by being combined with capacity-building programmes (in particular the Internal Security Fund, the Union Civil Protection Mechanism, the European Regional Development Fund, and the Cohesion Fund) and social innovation to support the entry into the market of developed technologies. Actions will also aim to ensure that there is a link between R&I and possible procurement (e.g. in the area of medical countermeasures).

12. Facilitating legitimate movement of passengers and goods into the EU, while preventing illicit acts

To enable legitimate travellers and goods to cross the EU's borders and enter it seamlessly, while ensuring internal security, the EU needs to invest more in developing its border management and related capabilities.

R&I actions under the **destination 'Effective management of EU external borders'** will further explore and develop future capabilities for European users in the areas of border management, customs and supply chain security, and civilian maritime security. Capability areas that will be further explored include border surveillance; facilitating travel; assessing and managing risk; strengthening the Schengen area without introducing internal border controls; maritime, aviation, land transport, cargo and customs security; supply chain resilience; detecting and identifying threats; the interoperability and cybersecurity of EU information systems and equipment; and safeguarding and promoting fundamental rights.

Technological and social innovation from research results and/or further research investment will also be promoted. Here, the new challenges the EU is facing, the changing policy context and the increasing need for efficiency and interoperability at EU level will be considered. Examples of emerging challenges may include threats of illicit flows of dangerous materials (explosives, radiological materials) and weapons across the EU's eastern borders as a result of the war in Ukraine; the potential for large-scale movements of people including those resulting from the instrumentalisation of irregular migration or from conflicts or social, economic, environmental and climate stress in the EU neighbourhood; the increased and evolving exploitation of migrants and trafficking of human beings across the EU's external borders, in particular vulnerable groups, including women and girls. All these emerging challenges have been exacerbated by the rapid adoption of new technologies by criminal organisations.

Research on border management capabilities should engage more and better with all stakeholders involved, including travellers and migrants themselves. It should better address aspects that are complementary to new technology or knowledge and – equally importantly – address aspects that enable the development of capabilities, such as organisation, procurement, education and training. It should also develop new approaches to safeguarding and promoting EU values and fundamental rights in the context of border management, with a special focus on human rights.

In terms of policy developments, Cluster 3 will support the implementation of an EU policy framework that is undergoing significant changes, with the updated EU Maritime Security Strategy and its Action Plan; the updated EU Arctic policy; the EU Drone Strategy 2.0; legislative proposals (presented in November 2023) to prevent and fight migrant smuggling and trafficking in human beings; the revised and amended Anti-trafficking Directive; and the upcoming legislative proposals on the digitalisation of travel documents and the facilitation of travel. The European Border and Coast Guard Agency (Frontex) will continue to be involved in policy, also taking into account the European Border and Coast Guard (EBCG) Capability Roadmap and the multiannual plan for European integrated border management, which include research and innovation, as will continue work with the EU Agency for the operational management of large-scale IT infrastructures (eu-LISA). Cluster 3 will further incentivise the use of EU space programmes' services for border management innovation where relevant. The EU will design increasing integration within this destination across the thematic areas and users' communities, as well as with other destinations in Cluster 3.

13. Tackling crime and terrorism more effectively and increasing the resilience of infrastructures

To respond to the changing threat landscape of serious and organised crime and of attacks on critical infrastructure, the EU needs to invest further in understanding the threats, including the underpinning societal issues, and in developing tools to prevent, detect and investigate them.

R&I actions under the **destination 'Better protect the EU and its citizens against Crime and Terrorism'** will continue developing European practitioners' capabilities to effectively prevent, detect and investigate terrorism, organised crime (such as illicit drugs production and falsified pharmaceutical products), cybercrime, the most harmful crimes based on sexual orientation, gender identity, or racial discrimination, and criminal aspects of behaviour on the internet, such as hate speech and cyber harassment or youth cybercriminality. Investment provides further support for modern information analysis, modern forensics tools (notably related to fast technological developments in traditional and digital forensics), lawful evidence collection, and the recognition of societal problems arising from various forms of crime. This destination will also prepare policymakers, practitioners, companies and the general public for tackling emerging and evolving threats, by identifying them early on, flagging them and making preliminary recommendations on how to deal with them.

Areas of new or increased focus will include the identification and investigation of criminal networks including emerging phenomena, such as insider threats related to critical infrastructure, counter-radicalisation efforts, protection of public spaces, and environmental crimes. The destination will continue to pay close attention to financial crimes, as a common denominator for most criminal activities. This concerns in particular terrorism financing, money laundering and tracking criminal profits in both fiat and crypto currencies. Considerable attention will be dedicated to countering corruption phenomena, an effort that will be coordinated and complemented by synergies, among others, with Cluster 2, to fully address the many forms corruption may take, such as bribery, influence-peddling, nepotism, or the abuse of power. Furthermore, innovative outcomes of research will be promoted, taking into account novelties, such as Europol's new role in the capability development cycle, from the development of topics to the putting into practice of project outcomes. Cluster 3 will incentivise the use of EU space programmes' services in this destination where relevant.

In terms of policy developments, Cluster 3 will support the implementation of the Counter-Terrorism Agenda for the EU, the Terrorist Content Online Regulation, the EU Strategy to tackle Organised Crime, the EU roadmap to fight drug trafficking and organised crime, the EU Drugs Strategy and Action Plan, the EU Strategy on Combatting Trafficking in Human Beings, the EU strategy for a more effective fight against child sexual abuse and the EU directive on the same topic, the EU initiative on countering the potential threat from unmanned aircraft systems, the anti-corruption Communication and proposal for a Directive on combating corruption presented by the Commission in May 2023, the EU action plan on firearms trafficking, the European strategy for a better internet for kids, the Communication No place for hate: a Europe united against hatred, as well as the obligations arising out of the EU's accession to the Council of Europe's Istanbul Convention on preventing and combatting violence against women and domestic violence, and the pending directive on combating violence against women and domestic violence[74].

R&I actions under the **destination 'Resilient Infrastructure'** will continue to enable the resilience of large-scale interconnected systems' infrastructures and the bodies that operate them in case of complex attacks, pandemics, natural and human-made disasters, or the impacts of climate change, including in more remote but critical areas, such as the European Arctic or outermost regions. Both the physical and digital aspects of critical infrastructure need to be considered, including specific challenges for cybersecurity.

Actions will also continue to focus on the development of upgraded systems, and the interoperability of existing systems, for operators' resilience and the protection of critical infrastructure to enable a rapid, effective, safe and secure response, without significant human involvement, to complex threats and challenges while also supporting emergency responders where their intervention is needed. Cross-sectoral cooperation will also be ensured, as well as risk assessments to ensure the resilience and open strategic autonomy of European infrastructures. The resilience of supply chains in general and maritime ports in

74. Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on combating violence against women and domestic violence. COM/2022/105, 8.3.2022.

particular needs to be improved, by evaluating weaknesses (such as dependence on non-EU actors) and ensuring that essential services continue to be provided.

Solutions should be adapted or adaptable to different types of critical infrastructure and suitable for different scales, meaning that they should also be able to be used by small critical organisations or bodies with few resources. The general public needs to be better aware of threats to the supply of critical services and of how to act in emergency situations.

Finally, the EU will develop capabilities to ensure that inclusive smart cities are resilient, secure and protected. The increasingly interconnected digital infrastructures and systems in a smart city bring increased risks of cascading effects.

Cluster 3 will continue to support the implementation of the directives on the resilience of critical entities (CER) and on network and information security (NIS2). Any (sub-)sector not covered by the directives also becomes part of Cluster 3's work once it can be shown to be critical. Cluster 3 will support the implementation of actions under the Council Recommendation of 8 December 2022 on a Union-wide coordinated approach to strengthen the resilience of critical infrastructure, which specifically calls on leveraging Union research and innovation programmes.

14. Increasing cybersecurity and making the online environment more secure

The increased digitalisation of the European economy, the growing number of incidents in cyberspace and the current geopolitical context demand further investment in cybersecurity research and innovation. Major technological trends include Edge, IoT, cloud, digital twins, metaverse applications and AI deployment, which need to be secured, and the transition to post-quantum cryptography. The cybersecurity of emerging technologies needs to be ensured.

R&I actions under the **destination 'Increased Cybersecurity'** will continue to support the EU's technological capabilities by investing in cybersecurity research and innovation to further strengthen its leadership, strategic autonomy, digital sovereignty and resilience. They will also help protect its infrastructures and improve its ability to prevent, protect against, respond to, resist, mitigate, absorb, accommodate and recover from cyber incidents, especially given the current context of geopolitical change. The approach is designed to provide open, free, stable and secure cyberspace, secure hardware and software systems, and a digital environment that can be trusted by the public and businesses, with full respect for fundamental rights. The operational risk management assessment cycle will be improved to include cybersecurity risks.

The destination will support European competitiveness in cybersecurity and European strategic autonomy, by protecting EU products and digital supply chains, as well as critical EU services and infrastructures (both physical and digital) to ensure their robustness and continuity in the face of severe disruptions. The destination will also encourage the development

of the European Cybersecurity Community, by further supporting the development of EU cybersecurity certification schemes and common standards, in close collaboration with the European Cybersecurity Competence Centre (ECCC).

Particular attention will be given to SMEs, who play a crucial role in the cybersecurity ecosystem and in overall EU digital single market competitiveness, by promoting security and privacy 'by design' in existing and emerging technologies.

Cluster 3 will continue to contribute to the EU Cybersecurity Strategy, taking into account the EU Cyber Resilience Act, the Cyber Solidarity Act, the Network and Information Security (NIS2) Directive, and will build on existing synergies with the activities of other programmes such as the Cybersecurity Skills Academy.

Cluster 3 will contribute to the ECCC's strategic agenda, in particular through work programme actions that can contribute to its comprehensive cybersecurity industrial, technology and research strategy. Cluster 3 will also strengthen synergies with the Digital Europe Programme and the ECCC and Network of National Coordination Centres.

Cross-cutting actions to support the expected impacts outlined above

Cross-cutting R&I actions under the **destination 'Strengthened Security Research and Innovation' (SSRI)** will support the expected impacts outlined above. This destination will increase the impact of the work carried out in the EU security R&I ecosystem and contribute to its core values, namely:

- a focus on the potential final use of the outcomes of security R&I;
- forward-looking planning of EU security capabilities;
- the development of security technologies that are socially acceptable, developed in quadruple helix[75], and that have added value for industrialisation, joint procurement, commercialisation, and the acquisition and deployment of successful R&I outcomes;
- safeguarding the EU's open strategic autonomy and technological sovereignty in critical security areas by contributing to a more competitive and resilient EU civil security technology and industrial base;
- experimenting with research and innovation programming; and
- helping to make the European R&I ecosystem more consistent.

The Strengthened Security Research and Innovation destination will create knowledge and value through research on topics (including technology, but also social sciences and humanities) that are not exclusive to only one security area, but cross-cutting to the whole Cluster. The aim is to reduce thematic fragmentation, as well as bridging the gap between research and impact, by bringing closer together actors from different security domains, and expanding the market beyond traditional thematic silos.

75. . through the interaction of public authorities, academia, industry and the public.

The destination will generate greater knowledge of standards or breakthrough research in matters that are of interest across all the thematic areas, including research on societal issues. It will promote innovation uptake, by using innovation procurement for example. It will continue generating new analytical tools, methods or metrics to support decision-making in R&I investment and to reinforce the innovation cycle itself from a process standpoint, thereby increasing its effectiveness, efficiency and impact. In addition, building on the Networks of Practitioners and Platforms funded under Horizon 2020, the results of the work of the knowledge networks for different thematic areas already funded under Horizon Europe will be used to consolidate the various communities, to create European sources of information for practitioners, in particular to better inform them about results of EU research projects, to share and spread knowledge and to better prepare responses to future complex security challenges. SSRI will continue contributing to developing the analytical capacity needed for structured long-term capability-based planning of R&I for civil security.

Alongside the work programme actions, and to maximise their impact, the Commission will continue to develop the following **supporting measures**[76]:

- Embedding security research in a forward-looking and **needs-driven capability development cycle** that triggers research, steers its implementation and capitalises on its outcomes. This approach will make it possible to identify common capability gaps and the investment needed for innovative solutions reflecting the specific needs of practitioners.
- **Working with EU agencies** – especially through the EU Innovation Hub for Internal Security – as well as initiatives such as the Union Civil Protection Knowledge Network to help ensure Cluster 3 work programmes respond to security practitioners' current and future needs.
- Further developing the **Community for European Research and Innovation for Security** (CERIS)[77] and better disseminating information about the outcomes of its activities.
- Supporting dialogue between security practitioners and suppliers of state-of-the-art security products throughout the entire capability development cycle; this can also contribute to developing the **EU's open strategic autonomy and its civil security industrial base**. This dialogue should lead to a comprehensive contribution to EU industrial policy. Also relevant for Cluster 3 are other initiatives presented by the Commission to support EU economic security, including with the aim to preserve a European edge on identified critical and emerging technologies related to civil security.
- Increasing foresight capability for security by carrying out foresight activities and identifying new trends in order to anticipate emerging critical technologies, and to respond in good time to future threats.
- Assessing the conditions for **secure, trustworthy and unbiased AI for security applications** within the applicable regulatory framework, as well as developing unbiased and representative **data sets for R&I**, in particular for testing, training and validating algorithms.

76. Most of these measures build on and develop those set out in the Commission Staff Working Document Enhancing security through research and innovation, 15.12.2021, SWD(2021) 422 .
77. Community for European Research and Innovation for Security (CERIS).

- Harnessing the potential of **standardisation** as a catalyst for market uptake in civil security.
- Continuing to operationalise the **synergies-by-design between EU civil security research and other EU funds** – see below for more detail.
- Improving the **visibility of security research** by means of events such as the annual security research event and an online presence (including social networks).
- Improving (and if necessary expanding) dissemination tools, to feed project results into policymaking and programming, at the Commission and in Member States and Associated Countries, **to support evidence-based policymaking and synergies** with other funding programmes.

Table 5 Overview of R&I expected impacts, cluster intervention areas, and Horizon Europe partnerships

EXPECTED IMPACT	INTERVENTION AREAS COVERED	EUROPEAN PARTNERSHIPS*
11. Reducing losses from natural, accidental and human-made disasters.	3.1.1. Disaster-resilient societies	N.A.
12. 12. Facilitating legitimate movement of passengers and goods into the EU, while preventing illicit acts.	3.1.2. Protection and security	N.A.
13. Tackling crime and terrorism more effectively and enhancing resilience of infrastructures.	3.1.2. Protection and Security 3.1.3. Cybersecurity	N.A.
14. Increasing cybersecurity and making the online environment more secure.	3.1.3. Cybersecurity	N.A.

In the table, partnerships are indicated for one impact even if some of them contribute to several impacts.

* The second batch of European Partnerships is not included in the first draft. Table 1 will be updated in the second draft and approved partnerships will be added once resolved.

INTERNATIONAL COOPERATION

Cluster 3 continues to require a specific approach to international cooperation to achieve the right balance between the benefits of exchange with key international partners (including relevant international organisations and offices), while at the same time ensuring the protection of the EU's security interests and the need for open strategic autonomy in critical sectors.

Under the destination 'Disaster-Resilient Society for Europe' (DRS), there is an established culture of comprehensive research collaboration with non-EU countries, taking account of the transnational aspect of different natural and human-made hazards and their causes (such as climate change). Therefore, under this destination, international cooperation will continue to be strongly encouraged, given the value of cooperating internationally, in particular in developing technologies for first responders to use. Cooperation with researchers and organisations from Ukraine will be encouraged for the EU to learn lessons from civil protection and contribute to the reconstruction of Ukrainian society. The explicit encouragement of international cooperation with relevant international fora will be assessed at the level of topics.

For the destinations relating to border management, the fight against crime and terrorism, infrastructure resilience and cybersecurity, international cooperation will be explicitly encouraged only where appropriate and specifically supportive of ongoing collaborative activities. Topics will be assessed as to whether they need to be limited to only selected international partners notably in light of the sensitivity of their subject matter and the need to maintain open strategic autonomy in critical security areas. In line with the Global Approach to Research and Innovation (Europe's strategy for international cooperation in a changing world) adopted by the Commission in 2021, the EU is committed to preserve openness in international research and innovation cooperation while promoting a level playing field and reciprocity underpinned by fundamental values. Targeted cooperation with Africa will be considered for topics covering issues of importance for Africa.

Synergies with other EU funding programmes

Cluster 3 will continue building and facilitating synergies with other EU funding programmes and instruments. This is particularly important for civil security, where solutions are often demand-driven in a market that is narrow, institutional, highly regulated, and sensitive or classified.

Synergies with other EU funding programmes and instruments are therefore crucial for enabling or facilitating the uptake of the results of research into deployable solutions, both from the demand side (funding for security practitioners and authorities, who are the users of security solutions), and from the supply side (funding for European innovators who develop and commercialise security solutions), in an approach with long-term capability development

planning at its core.

Cluster 3 will continue to operationalise the synergies with the home affairs funds: the Internal Security Fund (ISF) and the Integrated Border Management Fund (IBMF) in its two components, the Border Management and Visa Instrument (BMVI) and the Customs Control Equipment Instrument (CCEI). This will mean both facilitating the uptake of the results of Cluster 3 research by Member States and Associated Countries in their national programmes, and programming EU and specific actions with funding dedicated to taking up innovation resulting from Cluster 3 research.

Also, on the promotion of demand-side uptake, Cluster 3 will continue promoting synergies with the Digital Europe Programme, the European Maritime Fisheries and Aquaculture Fund (EMFAF), the Union Civil Protection Mechanism (Knowledge for Action in Prevention and Preparedness calls for proposals, early warning capabilities, and the training and exercises programme), the European Regional Development Fund (ERDF), the Cohesion Fund, the Neighbourhood, Development and International Cooperation Instrument – Global Europe instrument for the Southern and Eastern Neighbourhood and the Instrument for Pre-Accession, the Technical Support Instrument (TSI), the OLAF Union Anti-Fraud Programme (UAFP) and EU4Health. From the supply side, the promotion of the uptake of the results of Cluster 3 research could involve the Innovation Fund and, to a lesser extent, EU actions under the ISF and the BMVI, as well as Health Emergency Preparedness and Response HERA Invest.

Practical ways in which Cluster 3 will continue to improve and promote synergies include raising Member States' and Associated Countries authorities' and innovators' awareness of the opportunities for funding for uptake in other EU programmes and instruments; tracking and studying uptake of Cluster 3 projects' results in other EU programmes and instruments; planning actions in other EU funding programmes and instruments to fund innovation in civil security that takes up the results of Cluster 3 research. Although research funded under Cluster 3 will continue to focus exclusively on civilian applications, coordination with the European Defence Fund (EDF) and the EU Space Programme will also be sought in order to strengthen synergies.

Cross-cluster complementarities

Table 6 Overview of Cross Cluster Complementarities

RELEVANT CLUSTER	POSSIBLE COMPLEMENTARITIES
1. HEALTH	Preparedness of healthcare systems for different health emergencies (such as pandemics, pollution, natural disasters). Resilience of critical health infrastructures and tackling corruption in the health sector. Combating gender-based violence-related issues
2. CULTURE, CREATIVITY AND INCLUSIVE SOCIETY	Addressing corruption, radicalisation, extremism, disinformation/ misinformation, foreign interference and the manipulation of information (FIMI).
4. DIGITAL, INDUSTRY AND SPACE	Digital technologies for security (in border management, the fight against the trafficking of illegal goods, cultural heritage, etc.). Cybersecurity. Resilience of critical digital and space infrastructures. Use of Earth observation data (for example, on extreme climate events and natural disasters) and related modelling to design security policy and emergency actions.
5. CLIMATE, ENERGY AND MOBILITY	Operational response to climate-related disasters. Improving cybersecurity in mobility and transport. Resilience of critical energy and transport infrastructures.
6. FOOD, BIOECONOMY, NATURAL RESOURCES, AGRICULTURE AND ENVIRONMENT	Resilience of critical water, food and related infrastructures. Operational response to climate-related disasters (floods, wildfires and droughts). Combating environmental crime such as illegal waste dumping.

CLUSTER IMPACT SUMMARY

Cluster 4

DIGITAL, INDUSTRY & SPACE

Europe is facing the more direct consequences of climate change at social, economic and environmental levels. In addition, Russia's war of aggression against Ukraine and the COVID-19 crisis in 2020 came as unforeseen events that compounded the pressure already faced by industries in a rapidly changing technological and geo-political reality. In this context it is key to further support and accelerate just twin digital and green transitions of industries and the economy. This specifically requires, as a priority, substantial R&I investment, across different technology readiness levels, and seamlessly integrating technological, environmental and social objectives into innovation.

The **European Green Deal** strategy to achieve climate neutrality by 2050 includes significant components to encourage a carbon-neutral and less polluting industry, across sectors that are key to the twin transitions. The Fit for 55 legislative package is a key enabler for the EU in reducing its greenhouse gas (GHG) emissions by at least 55% by 2030 (compared to 1990 levels). It includes significant changes to the EU's Emission Trading System (EU ETS)[78] to phase out free allowances granted to EU manufacturers, which in turn will affect carbon prices, with possible effects on energy and carbon- intensive industries covered under Cluster 4. To scale up the availability of renewable energies under the REPowerEU plan, the European Green Deal Industrial Plan and under the umbrella of the Net-Zero Industry Act[79], more research is needed to enable the transformation of the EU industrial value chains across sectors towards full sustainability and climate neutrality, while remaining competitive. Copernicus and the applications developed from this exceptional space system will also contribute to the Green Deal strategy.

Recent legislative developments (such as the upcoming Ecodesign for Sustainable Products Regulation60 or the Critical Raw Materials Act[80]) introduce a strong focus on **circularity** to secure sustainability of supply chains. Yet, research, including emerging sciences, should also facilitate the move towards a **regenerative economy**. The principle of zero-pollution is gaining importance with the need to boost systemic change across economy and society, all industry sectors included, and the need for addressing pollution at the source. The adoption and production of net-zero technologies must speed up, and the way the EU produces and consumes needs to change in a systemic way. The EU has the potential to become a leading player in the net-zero industries of the future, but further investment is needed.

Resilience and technological sovereignty have become renewed priorities for the EU due to the current geopolitical and economic context that exposed vulnerabilities in critical value chains, including of microchips, critical raw materials-[81], critical medicines[82] and innovative materials and biotechnologies. In this context it is crucial to reinforce Europe's position in digital technologies, Artificial Intelligence, robotics, secure communication, high-performance computing, biomanufacturing, advanced and sustainable manufacturing technologies, net-zero industry, sustainable raw and innovative materials and the circular economy because

78. Approved by the European Parliament in April 2023.
79. COM (2023) 161: Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net Zero Industry Act).
80. Communication from the Commission. A secure and sustainable supply of critical raw materials in support of the twin transition, COM(2023) 165, 16.3.2023.
81. Communication from the Commission. A secure and sustainable supply of critical raw materials in support of the twin transition, COM(2023) 165, 16.3.2023.
82. Communication on addressing medicine shortages in the EU | European Commission (europa.eu)

of their strategic and environmental spillover effects to multiple domains across science and industry. The development of critical technologies in space will also contribute to the strategic autonomy of EU.

The **EU's Digital Decade policy programme** sets out an encompassing vision, objectives and quantitative targets for the **digital transformation of the EU by 2030** along four dimensions: skills, infrastructures, the digital transformation of businesses and the digital transformation of the public sector. The European Chips Act aims at doubling Europe's current global market share in semiconductor chips to 20% by 2030, while strengthening Europe's research and technology leadership, as well as capacity towards more advanced and faster chips (semiconductor and quantum), and addresses the skills shortage, attract new talent and support the emergence of a skilled and diversified workforce. Horizon Europe investment helps achieve these ambitions. To this end, Cluster 4 aims at decisive progress and an internationally leading position for Europe in the key digital and space technologies that will be most important in the next ten years, including AI, advanced computing, photonics, quantum technologies, microelectronics, industrial internet-of-things and next generation of internet. They contribute to Europe's long-term strategic autonomy while preserving an open economy in the digital sector, and that will bring about a secure, inclusive and sustainable digital transformation that puts people at its centre, in line with EU core values and fundamental rights[83].

For instance, developing secure **and inclusive virtual worlds**, and taking up all the possibilities they offer is a pressing challenge. This Cluster will pull together the different technology strands to create a distinctively European capability in this area. In addition, the accelerated advancement and societal impact of **Artificial Intelligence**, from deep learning to foundational models and language technology, is calling for a strong strategic response to effectively combine European strengths in algorithms, data governance and high-performance computing for developing an agile and trustworthy AI economy in Europe. Various recent or upcoming EU legislation will enhance the sharing and exploitation of data (Data Governance Act, Data Act, the Interoperable Europe Act, the Digital Product Passport) and the development and take up of trustworthy solutions (AI Act). The cluster will support the different actors, including scientists and SMEs, to comply with, and fully exploit these new regulatory frameworks.

The cluster will also promote cutting-edge collaborative research across technology readiness levels in the digital and space fields and on other key enabling technologies to ensure that Europe will be at the forefront of ICT and space R&I in the coming decades.

In line with the regulation on the Strategic Technologies for Europe Platform (STEP), research capacities need to be strengthened for key enabling technologies, such as quantum,

83. For more information, please see the dedicated page on European Declaration on Digital Rights and Principles.

photonics, cybersecurity or advanced materials. A seamless integration of technological, environmental and social innovation remains a priority. Focused on mutually reinforcing elements of human-centricity, sustainability and resilience while addressing gender, racial and other social biases in the design, development, and deployment of technology, it should drive the deep transformation of industrial and innovation ecosystems. For this there will be continued emphasis in including expertise from social sciences and humanities in appropriate activities under Cluster 4. The cluster will continue links with the New European Bauhaus.

There will be increased attention given to policy priorities and challenges such as security, open strategic autonomy, while preserving an open economy and standardisation.

HOW WILL CLUSTER 4 MAKE A DIFFERENCE?

Expected impacts

Cluster 4 will programme investment to achieve the six following expected impacts.

15. Achieving global leadership in climate-neutral, circular and digitised industrial and digital value chains

Supporting net-zero manufacturing is a key objective of the Net-Zero industry Act[84] and has a crucial role to play in the transition towards a green and sustainable society, going from 'smart factory' to a 'smart sustainable value chain'. This includes flexible and 'first-time right' manufacturing systems and processes for innovative and sustainable materials, components and products, based on advances in manufacturing technologies, data spaces and digital twins. Smart manufacturing will help develop the materials and products needed to support net-zero and less polluting industries. Breakthrough technologies to be exploited beyond 2030 will also play an important role.

There is much scope for improvement in circularity technologies applicable to different value chains, with special attention needed for product design, re-use, disassembly, remanufacturing/upgrading, recycling, and 'Zero-X' – zero defects, zero breakdowns and zero waste. 'Servitisation' – the transformation from selling physical products to providing services for and through them – needs the combination of green and recycling technologies enabled by leveraging the data available in the industrial environment. Digital technologies, like big data, advanced computing, and networking (including quantum), AI, robotics, photonics and the industrial virtual worlds will transform the practices of research, design and engineering, with better performing net-zero solutions and increased productivity in all sectors. Quick-response services can support hyperflexible production using, e.g. trustworthy AI and digital twins, with digitally enabled certification and qualification of processes and products. It will be important to develop and test different circularity technologies throughout the entire value chain and

84. Proposal for a regulation on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net Zero Industry Act), COM(2023) 161, 16.3.2023.

life cycle[85], and analyse market, cooperation, governance and business case conditions to facilitating deployment further developing value chains for circularity and enabling systemic changes for specific markets and where possible across sectors, including fostering synergies between organisations along the value chains, such as social economy actors.

The development of new and cross-cutting technologies will boost the transformation of existing value chains and the creation of new ones. One example is the addition of the bio-dimension to the existing technological base, particularly in the context of manufacturing (biomanufacturing), processing and materials. Energy-intensive industries need to embrace the circular economy as a key pillar in the design of their value chains. This will be fundamental to their resource efficiency (material, energy and water). Particularly important in this context is the innovative upcycling of secondary raw material and waste and the development of sustainable and resource-efficient industrial processes. Further development and deployment of technologies identified in the ERA industrial technology roadmaps for circular technologies and for low-carbon technologies will be essential to achieve this goal. Manufacturing processes, supply chains, cyber-physical systems or cities will become more climate neutral and less polluting, and circular solutions will include AI and digital twins, and the deployment of common European data spaces like those under the Digital Europe Programme. These and other breakthrough technologies will be key for developing and implementing the pathways and new value chains that the Hubs4Circularity[86] project will require.

The EU has set an ambitious goal for Europe to become the first climate-neutral continent by 2050. In some areas the key solutions for achieving significant reductions in emissions are already in the market. In crucial parts of the economy, as is the case for energy-intensive industries, many of the tools needed for such a significant reduction are still at an earlier stage of industrial or commercial development. Reducing these emissions in industrial sectors will require coordinated action throughout value chains to boost and accelerate innovation and deployment of all mitigation options, including: i) demand management; ii) energy and materials efficiency; iii) integration of renewable energies (use of green hydrogen or electrification), and circular material flows; iv) abatement technologies for emissions and pollution; and v) R&I on systems ´ modelling and management scenarios and vi) transformational changes in production processes. Other industries that make use of these industrial outputs, e.g. consumer products and construction, also face the need to modernise and can thereby help support transformation across the value chain. The process industries' climate neutrality goal is also strongly related to the objective of becoming independent from fossil fuels and fossil fuel imports and increasing the proportion of renewables in energy supplies.

85. See the ERA industrial technology roadmap for circular industrial technologies and business models in three industrial ecosystems: textile, construction, energy-intensive industries, January 2023; cross-sectoral key findings apply also to the approach needed for circularity beyond the three ecosystems addressed.
86. Hubs4Circularity community of practice.

To successfully move from innovation to deployment, a more effective transfer from small-scale industrial demonstrators to first-of-a-kind climate-neutral demonstrators is needed. In line with the EC 'demonstrators report', the aim will be to consolidate the relevant work strands to accompany the deployment mechanism for these industrial technologies in FP10[87]. It is also important to pursue breakthrough innovations and completely new approaches, with a high capacity to drastically reduce air pollutants, CO2 and GHG emissions at the source. Research and pilot projects would be needed on how low-tech alternatives combined with high-tech and data-driven innovation can reduce the climate and environmental footprint of products and sectors. This would include agri-food value chains, electronics, plastics, packaging, textile materials, manufacturing and reuse[88], repairing or transport, and drive them towards circularity. Importantly, moving from innovation to deployment will require significant human capacity, including workers with the right skills across key sectors, who are provided with quality-job opportunities. The Cultural and Creative Sectors will also contribute to move from innovation to deployment. Europe's cultural depth and its human-centric approach to technology, are a perfect breeding ground for market-creating design.

Hubs4Circularity is a tool that allows for place-based innovation, whenever possible in conjunction with similar existing concepts or technology infrastructures, such as hydrogen valleys[89]. This tool could build on the completion of projects devoted to industrial symbiosis research and on innovations resulting from ongoing hubs for circularity projects. Hubs4Circularity should deal not only with first-of-a-kind demonstrators, but also with the transformation of existing plants. Ultimately, Hubs4Circularity should combine the need for water and energy savings, and promote the use of secondary raw materials. It will require that the place-based development of recycling technologies and materials research also benefits from cooperation between energy-intensive industries and cities and regions, including responsible sourcing, tracing and recycling of materials. Therefore, it will be pivotal to engage with Member States and regions in delivering on any commitments to give additional funding.

Across industries, the human dimension (including gender differences) will be stressed via the Industry 5.0 paradigm (related to expected impact 20).

16. Achieving technological leadership for Europe's open strategic autonomy in raw materials, chemicals and innovative materials

A paradigm shift, as regards the availability, development, use and disposal of chemicals and materials is required to guarantee Europe's open strategic autonomy, technological sovereignty and capacity to deliver on the twin green and digital transitions.

To enable such a shift, an innovative, strong European R&I ecosystem for circular chemicals and materials is needed working across different technology readiness levels. The forthcoming communication on advanced materials will be a stepping-stone for framing this ecosystem. Bringing knowledge and skills together across the materials' value chains is key to ensuring

87. The next EU funding programme for research and innovation.
88. Also linked to the proposed Partnership on Textiles
89. See also: European Digital Innovation Hubs | Shaping Europe's digital future (europa.eu).

that this shift can materialise. The requirements of the European Green Deal for safety, sustainability and circularity must be considered across the life cycle of a chemical or material. The 2022 Commission Recommendation[90] on 'safe and sustainable by design' sets out a new framework on how to achieve these objectives. Communicating results, impacts and achievements is important not only to the scientific community but also to stakeholders and people affected by the new approaches and innovative thinking.

R&I activities should contribute to strengthen EU's critical raw materials capacities along all stages of the value chain, increasing our resilience by reducing dependencies, increasing preparedness and promoting supply chain sustainability and circularity, in line with the Critical Raw Materials Act.

All critical raw materials should be addressed – particularly those used in strategic sectors like renewable energy, electromobility, energy-intensive industry, digital, and aerospace, and the corresponding manufacturing technologies. It is necessary to improve the energy and process efficiency of extractive and processing activities and minimise their environmental impact, including GHG emissions. As regards raw materials, R&I on exploration, sustainable sourcing from extraction to secondary raw materials as well as increasing efficiency in the use of critical raw materials are important. Advancements need to be made on finding options for replacing critical raw materials with other (advanced) materials offering at least the same functionality and taking into account the existing environmental concerns.

Advanced materials (including amongst others nano- and 2D materials) and chemicals are designed with functionality in mind. Compared to conventional materials, they have novel properties that significantly step up performance. For the design and development phase of advanced materials there is a need for: i) research and technology infrastructures (e.g. open innovation testbeds, analytical facilities); ii) innovative digital tools opening up new avenues for design (smart sensing and imaging, making use of artificial intelligence, machine learning, robotics and high-performance computing); and iii) smart data management. New digital tools are needed such as common data spaces, digital twins, industrial virtual worlds, as well as novel (autonomous) design, synthesis, development, characterisation and fabrication tools as well as continuous training of scientists on these new tools. To secure unimpeded market entry, appropriate test methods are needed. New chemicals and materials should be developed using the 'safe and sustainable by design' framework and with the efficiency and circularity of materials in mind, also for their inclusion in products. This calls for tools, models and data for robust 'safe and sustainable by design' assessment, including animal-free new approach methodologies and systematic life-cycle assessments. Bio-based advanced materials/chemicals and the integration and interaction of biological and artificial materials and components offer new opportunities to reduce resource dependencies and maintain sustainability.

90. Commission Recommendation of 8 December 2022 on establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials, C (2022)8854, 8.12.2022.

Achieving the circularity of both raw materials and advanced materials is a key future challenge. Establishing new material flows, recovery, recycling and upcycling of materials from waste are challenges in themselves, but they also require information sharing along and across value chains and development of new business models allowing to foster innovative solutions related to technological progress, such as in materials design. Uptake of advanced materials as well as a more efficient use of materials should be fostered in product and materials-based technology developments. This also requires new business models to be developed for the deployment of circular technologies and value chains as well as for providing product-as-a-service models, on-demand manufacturing, take-back-schemes and other service-based businesses. Strong support to SMEs is required so they can thrive in this materials ecosystem.

17. Developing an agile and secure single market and infrastructure for data-services and trustworthy artificial intelligence services

The next stage of the data economy will shift data flows from the consumer-to-business model to business-to-business, business-to-consumer, consumer-to-consumer, business-to-government and government-to-business models. Cluster 4 will continue to support technologies that are crucial for the next stages of the data economy, such as privacy-preserving technologies and compliance technologies, source and transaction integrity (such as blockchain), and technologies underpinning interoperable and compliant industrial, public and personal data spaces and secure data exchanges. Rebalancing the data, computing, and learning capacity across the cloud-to-edge/internet of things continuum will let businesses, public organisations and individuals exploit data for trustworthy and bias-free decision-making. Wide availability of reliable data, like from the European data spaces in the Digital Europe Programme, together with new interactive, immersive and context-aware technologies – digital twins, cyber-physical systems, internet of things and virtual worlds – will make this easier than ever before. This will help all people groups benefit from the power of data and AI in a fair, unbiased and compliant way.

Industrial virtual worlds that are open and interconnected bring alternative but realistic and coherent views on what are widely distributed, diverse and complex devices, processes and value chains. Beyond visualisation and simulation, and thanks to new types of interfaces (like XR/VR), secure data sharing and distributed computing technologies, they allow for safe and natural ways of interaction and control, high level of response to local events, real-time optimisation and dynamic re-configuration in key application areas like for: i) the integration of renewable energy sources, ii) smart farming, iii) agile supply chains and logistics, and iv) hyperflexible manufacturing and manufacturing-as-a-service. Similarly, data-driven tools, AI, language technology, adaptive and self-programmed robotics, and new energy-aware programming solutions will improve operational and energy efficiency in lead sectors like healthcare, manufacturing, mobility, and the energy sector itself.

Quantum technologies will further expand the data economy in high value-added areas where traditional approaches struggle to deliver, for instance, highly secure communication of critical data, or on exponentially complex simulations, machine learning and optimisation. Quantum networks will provide highly secure, tamper-free data storage and transmission, which can be critical in situations where the integrity and confidentiality of the data are paramount, like in the health sector, smart cities, energy systems or other critical infrastructure.

18. Achieving open strategic autonomy in digital and emerging enabling technologies

Cluster 4 ensures Europe's strategic autonomy while preserving an open economy in those technologies that will be key for a deep digital transformation of industry, public services and society, while fully playing its enabling role in the twin transition.

As set out in the European Chips Act, the top-priorities are to i) strengthen processes undertaken at critical stages in the semiconductor and quantum chips value chain, including chip design and manufacturing technologies, and ii) address the use of new materials and green technologies, energy efficiency and the integration of circularity and life-cycle assessment. Cluster 4 will address high value-added hardware needs for core, cloud and edge, fast-sensing, low-latency and high-bandwidth data transmission, and help secure the supply of critical components for key markets, such as automotive, health, automation and mobility systems. For this purpose, significant human capacity will be required in chip manufacturing to ensure: (i) the strengthening of processes undertaken at critical stages in the value chain; and (ii) that workers can take up quality jobs created as part of these priorities, including through the activities undertaken by the joint undertaking initiative.

In addition, future needs in microelectronics (such as performance, size, cost, energy efficiency, environmental impact, new materials, concepts, architectures, integration) may also be addressed to make sure Europe's microelectronics industry remains competitive. Opportunities may come from non-volatile memories, spintronics, in-memory computing, neuromorphic and other emerging technologies. Photonics research will lead to fast and versatile sensing and imaging, and energy-efficient building blocks for networks and data centres. The cluster will also push for chip-level integration of photonics and optoelectronics.

The cloud/edge/internet of things will be transformed into an agile and situation-aware infrastructure that brings data to where and when it is needed. Within these smart digital infrastructures, end-to-end artificial intelligence, from the core to the edge and across all technology layers, will be key for on-demand supply of optimal data-, communication-, and computing resource orchestration, with optimal use of energy while preserving privacy and ensuring resilience. European sovereignty in the cloud-edge server market will be strengthened through the power of open-source software, complementing the RISC-V based European Processor Initiative that aims to increase Europe's independence in high-performance computing hardware.

Cluster 4 will transform the user experience. It will push the frontiers of virtual and extended realities (VR/XR) and of open, human-centric virtual worlds for industry, entertainment and arts, public services and people alike, e.g. by leveraging social innovation. It envisages a vibrant R&I ecosystem that strategically joins-up research and development on sophisticated VR/XR optics and displays, multimodal human-computer interaction, authoring tools, real-time spatial computing, rendering, integration and application research. Improved sensing, fast processing and low-latency will be challenging for the underlying cloud/edge/Internet of things.

Along similar lines, the way in which the virtual world meets the physical world will continue to evolve, thanks to all kinds of robots and other smart devices that involve self- and context-awareness, spatial intelligence, exploiting the best in bias-free AI, engineering and design for game-changing physical characteristics, functional or cognitive capabilities, acute perception, autonomy and safe interaction.

Artificial intelligence underpins many of these changes and Cluster 4 will strengthen and consolidate R&I in this area. For example, today's generative models are a preview of how virtual worlds and multimodal user-experiences could be produced on-demand. Research on core learning and analysis techniques (incremental, frugal and collaborative), as well as next generation smart robotic systems, will keep Europe at the cutting edge of AI. Artificial Intelligence is also key to keep the competitiveness and strategic autonomy of the EU scientific sector.

Europe's long-term competitiveness in the digital area requires continuous scouting and early, low-TRL cross-disciplinary work on new and emerging technologies, dissociated from the main roadmaps. This would encourage collaboration in research and cross-fertilisation between disciplines and sectors on new approaches in: (i) microelectronics; (ii) power electronics; (iii) photonics and photon/phonon/spin/electron integration; (iv) unconventional, hybrid, neuromorphic, nature-inspired or bio-intelligent paradigms; and (v) novel systems and infrastructure architectures.

Europe's strength in quantum technologies (including in quantum communications and optical satellite communications, etc.) is a strategic asset for its future security and independence. Cluster 4 supports early and mature quantum technologies and stimulates their industrial uptake, e.g. through experimentation and testing environments for integrating them into standard industrial design and manufacturing.

Equally transformative, two-dimensional materials (2DM) could positively affect many industries, including ICT. While further exploring the vast range of 2DMs, Cluster 4 will also work towards completing a fully European supply chain and scaling up the development and piloting of 2DM technologies and devices for more industrial fields.

19. Achieving open strategic autonomy in global space-based infrastructures, services, applications and data

People in Europe should be allowed to reap the benefits of space services, data and applications. Today, many sectors of the EU economy rely on services, data and applications from space. This includes satellite navigation for mobility and transport, agriculture and land management, banking and other financial transactions and energy management. In addition, satellite Earth observation is very important for i) environmental monitoring and follow-up, ii) mitigating pollution and climate change, whether on land, in the air or at sea and iii) emergency management situations. It plays a key role in the implementation of the European Green Deal objectives. Finally, some other technologies that also play a crucial role in security and resilience when dealing with threats, natural or human, include: (i) space-based situational awareness; (ii) telecommunications; (iii) satellite navigation and positioning; and (iv) in-space services. The EU space industry is an important part of the EU economy, being a global market leader in some sectors while being more of a challenger in others. Cluster 4's space component will help further strengthen the EU's capacity to: (i) conceive, develop, operate and exploit competitive space technologies, systems and data and the associated services and applications in space and on the ground; and (ii) develop new flexible, scalable, secure and sustainable system approaches, ensuring freedom of action and autonomy. The non-dependence and resilience of EU space technologies and strategic assets also need to be ensured. Space is a sector that helps to ensure that the EU is not dependent on other parts of the globe when security and/or political independence aspects come into play. It also helps to: (i) protect EU infrastructure and strategic assets from damage, be it from natural hazards or human threats; and (ii) increase the ability of EU infrastructures to scale up and adapt.

20. Digital and industrial technologies driving human-centric innovation

New ways of working, assisted by technologies for physical or cognitive augmentation (exo-skeletons, digital twins, collaborative AI, virtual and extended reality) will increase efficiency, safety and quality of work, provided they are trustworthy, safe and reliable, as well as human-centric and free from gender, racial and other social biases by design. Within the dynamic context of flexible organisation and process flows, workers will have to be empowered to co-create their new forms of working and collaboration within and across organisations, through participation, social innovation or living labs, where social economy actors and local grassroots initiatives are of particular importance. New job profiles and skills will emerge, often requiring digital competence, in addition to social and green skills (e.g. awareness of impact, circularity options). Continuous learning, through formal training, on-the-job learning or being immersed in virtual worlds, combined with appropriate certification and reward mechanisms can boost the attractiveness of careers in many sectors, including manufacturing. A new dynamic, in the spirit of Industry 5.0, will be brought to the workplace through better human interaction with production technologies, open innovation, supporting young professionals' innovations in e.g. manufacturing, as well as participation of new actors, such as fablabs. Digital environments and virtual worlds will enable new forms of collaboration in generating new product and process ideas, assisted by digital twins and AI, in an inclusive, trustworthy and ethical fashion.

Just like today's internet, the future internet will drive industrial, social and cultural innovation. The cluster will develop technologies for an inclusive, gender-equal, trustworthy and human-centric internet. This will build on a more resilient, sustainable, and decentralised architecture, empower end-users with more control over their data and their digital identity, and enable new social and business models that respect European values. The cluster will also spearhead the use of virtual worlds and digital twins where they can make a real difference. Industrial virtual worlds could increase productivity, improve working conditions and access to work, and address and anticipate skills gaps for highly complex products/services or for safety-critical operations. Smart communities and 'citiverses' can empower public authorities and people to fulfil their aspirations.

To reach the ambitious goal of achieving trustworthy AI, 'compliant by design' with the AI Act – challenges such as accuracy, robustness, transparency and efficiency have to be addressed, along eliminating biases in data entry to assure fairness in light of individual differences, e.g. in gender or age, and intersectional diversity. Increasing the cognitive level of AI systems (like from combining data-driven and symbolic learning) is crucial for their wider uptake and acceptance. Smart 'technology-for-trust' (e.g. blockchain for identity and transaction tracking, AI to counter biases, deep-fake recognition, fact checking) will also have a role. The Cluster will focus on particularly on generative AI (addressing algorithms, data and computational resources), foundational models and language technologies to gain strategic autonomy in this area. This is expected to trigger a whole range of new applications in entertainment, education and commerce, starting with assisted and virtual content production, and on-demand synthetic media. Beyond these, the possibilities in industrial settings (e.g. robotics, training, process planning, quality assurance), in public services and public administrations are largely untapped. Involvement of social sciences and humanities will help bring benefits and respect for European values.

Specific measures are needed to allow start-ups and smaller companies to use and benefit from AI, data (including by enabling access to the high-performance computing power needed), photonics and robotics, and to play an active part in developing the next generation of smart technologies within a diverse and open European innovation ecosystem. Similarly, the responsible use of AI in science, research and engineering is going to be key for keeping up the scientific and technological global competitiveness of the EU.

A well-functioning European ecosystem of digital commons, based on open technologies and driven by European values, and a thriving culture of collaboration and social innovation are essential for ensuring sovereignty, trust and user empowerment. New software engineering techniques are needed that are applicable from core to edge and across the entire software stack to build the open distributed systems that the cluster envisages. AI-driven as well as low-code methodologies will help address shortages of digital skills, increase productivity and allow for point-of-use configuration and personalisation.

Ultimately, industrial and digital technologies should empower everybody, from individuals to small and large public and private organisations, to actively take part in co-creating Europe's green and digital future. The cluster will engage with people at a broad level to address ethical and societal concerns and examine legal and regulatory questions. An integral part of the human-centric approach will be to pay attention to the impact on physical and mental health and well-being, e.g. in the context of virtual worlds and advanced interfaces, or on society like for democracy and mitigating divides. To fully achieve these objectives, synergies with the Cultural and Creative Industries will be essential.

Table 7 Overview of R&I expected impacts, intervention areas, and Horizon Europe partnerships

EXPECTED IMPACT	INTERVENTION AREAS COVERED	EUROPEAN PARTNERSHIPS*
15. . Achieving global leadership in climate-neutral, circular and digitised industrial and digital value chains	4.2.1. Manufacturing technologies 4.2.4. Advanced Materials 4.2.8. Circular Industries 4.2.9. Net-zero and less polluting Industries	Made in Europe Process for Planet Clean Steel Textiles of the Future
16. Achieving technological leadership for Europe's open strategic autonomy in raw materials, chemicals and innovative materials	4.2.5. Artificial intelligence and robotics 4.2.7. Advanced computing and big data 4.2.1. Manufacturing technologies 4.2.8. Circular Industries 4.2.9. Net-zero and less polluting Industries	Raw Materials for the Green and Digital Transition Innovative Materials for EU
17. Developing an agile and secure single market and infrastructure for data services and trustworthy artificial intelligence services	4.2.2. Key digital technologies 4.2.3. Emerging enabling technologies 4.2.5. Artificial intelligence and robotics 4.2.6. Next generation internet 4.2.7. Advanced computing and big data	Photonics Partnership Artificial Intelligence, Data and Robotics Made in Europe Agriculture of Data
18. Achieving open strategic autonomy in digital and emerging enabling technologies	4.2.2. Key digital technologies 4.2.3. Emerging enabling technologies 4.2.5. Artificial intelligence and robotics 4.2.6. Next generation internet 4.2.7. Advanced computing and data	Artificial Intelligence, Data and Robotics Photonics Partnership Virtual Worlds

19. Achieving open strategic autonomy in global space-based infrastructures, services, applications and data	4.2.10. Space, including Earth observation and IRIS2	Globally Competitive Space Systems
20. Digital and industrial technologies driving human-centric innovation	4.2.6. Next generation internet 4.2.5. Artificial intelligence and robotics 4.2.1. Manufacturing technologies	Artificial Intelligence, Data and Robotics Made in Europe Photonics Partnership Virtual Worlds

In this table, partnerships are indicated for one impact even if some of them contribute to several.

INTERNATIONAL COOPERATION

This cluster will emphasise multilateral cooperation in areas of common interest, highlighting Europe's strong position in sustainability, and pursuing a level playing field common standards and, where appropriate, reciprocity. Collaborative R&I will be complemented by industrial and policy discussions to achieve these aims. The following list comprises examples of international cooperation.

- The Global Approach to Research and Innovation[91] will serve as a guide to implementing the international dimension of Horizon Europe. An additional push for international cooperation will be made in strategic areas of mutual benefit, including in the context of the new EU-Latin America-Caribbean initiative being prepared and the AU-EU Innovation Agenda.
- The cluster will increase engagement with the enlargement countries, including countries in the Western Balkans and open some of the existing co-programmed partnerships within Cluster 4. Also, steps will be taken to support collaboration between industry and academia and participatory value creation as well as disseminate study results.
- The EU will increase its technological sovereignty while sustaining productive relations with its strategic partners in Europe and beyond. It needs to reduce its dependency on non-EU countries for key strategic segments of technology value chains. It will need to strengthen its strategic technological capacities in cooperation with close partners while at the same time preventing attempts by non-EU countries to control strategic companies in the EU.
- The EU will develop common standards and interoperability, including in the regulatory context of manufacturing technologies, digital technologies – particularly 5G and beyond Artificial Intelligence (focused on ethics and data) – and in-space services.
- The EU will promote a human-centred internet that supports ethical and social values, by strengthening collaboration with non-EU countries, attracting internet talent.
- The EU will increase its technological sovereignty in raw materials, particularly critical raw materials, and advanced materials while sustaining productive relations with the EU's strategic partners.

91. European Commission: Global Approach to Research and Innovation, www.science-diplomacy.eu

- The EU will build on the positive experiences from previous cooperation on manufacturing with Canada, Japan and South Korea.
- The EU will step up its cooperation with its closest partners on the development of integrated production and services networks.
- Specifically for space, international cooperation is essential for: (i) technological developments (although there are areas and topics for which the security or strategic interests of the EU are at stake and participation must therefore be limited or only include trusted partners); (ii) extending the use of the EU space programme components, such as Galileo and Copernicus, in other regions of the world, strengthening Europe's geopolitical role; and (iii) space sciences (e.g. astrophysics/cosmology/astroparticle physics) and scientific exploitation of data.

While retaining its essence of openness to international cooperation, the cluster will ensure the safeguarding of the EU's strategic assets, interests, autonomy, and security in critical areas such as 5G/6G, AI, quantum computing, chips or space technologies.

Synergies with other EU funding programmes

Cluster 4 addresses enabling technologies, more than specific sectoral results. As such, the transfer of these results to specific settings is a challenge that lies beyond the cluster. Here synergies with specific sectors and place-based innovation ecosystems are needed. More proactive approaches to foster certain synergies will be developed under this strategic plan.

- Synergies with the **Innovation Fund**: In 2023, a coordination and support action co-funded by Cluster 4 was included in Cluster 5 to encourage the take-up of Horizon 2020 results by the Innovation Fund, including Cluster 4 priorities in energy-intensive industries, carbon capture utilisation and storage and the new space ecosystem (i.e. the Cassini initiative). Topics in these areas under the 2023-2024 work programme encourage GHG avoidance methodology under the Innovation Fund to be used and exploitation plans to be developed in line with the Innovation Fund's criteria. It is expected that the efforts to foster synergies with the Innovation Fund will continue into the second half of the programme.
- Synergies with the **Digital Europe Programme**: The Digital Europe Programme aims at deploying digital data, communication and computing capacities across Europe and increasing their take-up in industry, businesses, research institutions and public services. It also aims at developing people's digital skills and increasing the number of ICT professionals. To achieve these aims, there is potential to implement downstream sequential synergies with Cluster 4. Data spaces deployed under the Digital Europe Programme will use compliance and interoperability technologies developed under Cluster 4, but data spaces can also be made available to Horizon Europe stakeholders, which can lead to upstream sequential synergy. This is also relevant for experimentation and testing facilities, as once validated in the labs, the technology can be tested in a real-life environment. In particular, 'Destination Earth' will greatly benefit from integrating cutting-edge results from the cluster (computing, digital twins, virtual reality,

space technology), while in turn serving as a powerful data-generation infrastructure for advanced experimentation in Horizon Europe projects. The Digital Europe Programme (including 'Destination Earth') is also relevant for space-related activities, especially when it comes to Copernicus as it can provide Earth system modelling and data assimilation.

- Synergies with the **Connecting Europe Facility** (CEF): The CEF programme offers opportunities to fund the deployment of innovative solutions developed in the EU's R&I framework programmes (specifically the infrastructure needed for enabling their roll-out), particularly in the digital area (e.g. advanced connectivity in light of future requirements for Web 4.0 and virtual world) and for the digital part of space related activities.
- Synergies with the **ERDF** including European Territorial Cooperation (Interreg): These could involve possible scale-up of results, also through the ERDF and ESF+, within the topics implementing the Processes4Planet partnership. The ERDF and smart specialisation have potential for parallel or downstream sequential synergies, based on existing guidance documents. An example of leveraging synergies between Cluster 4 and the ERDF could be a structured transition process for pilot lines for key digital technologies.
- Synergies with **InvestEU**, e.g. to provide HE resources as funding for specific, thematic products to implementing partners which will provide financial support and guarantees where needed for riskier 'new space' actors and activities. InvestEU can mobilise extra funding for near market scaling up or for achieving infrastructural needs, e.g. to support i) demonstrators and the deployment of low-carbon technologies, green technologies for climate-neutral and less polluting energy-intensive industries, and for early-stage growth companies and first-mover uptake of quantum technologies, and ii) the uptake of advanced materials with improved functionalities to accelerate the green transition of different industrial sectors towards future European Green Deal driven markets. Under InvestEU advisory Cluster leads can procure studies clarifying the potential and design of financial products and needs.
- Synergies with the **EU space programme**: Space R&I forms the foundation and provides technological input for developing the programme's different components (Galileo, EGNOS, Copernicus, SSA, GOVSATCOM) + IRIS2.
- Synergies with the **EDF**: The EDF, as well as space and other R&I within Cluster 4 can lead to dual-use developments (spin-ins & spin-offs).
- Synergies with the **ESF** and the **Erasmus+** programme can be further explored to create the framework for upscaling the Horizon Europe project results as part of the two programmes.
- Support for the objectives of new or updated EU environmental acquis, e.g. in the context of the zero pollution action plan.
- The **LIFE programme** enables sequential downstream funding for innovations, by granting bonus points in the evaluation when proposals directly use results of Horizon-funded projects. LIFE's subprogrammes (notably Climate Change Mitigation and Adaptation) have several projects in industry for reducing greenhouse gas emissions and air pollutants.

- Synergies with Euratom, for example applications of AI and robotics in nuclear medicine, robot remote handling in the nuclear field, analysing of images and other data from nuclear facilities for remote inspections, digital twins of nuclear facilities, simulations and training for preparing for nuclear incidents etc.

Cross-cluster complementarities

Table 8 Overview of Cross Cluster Complementarities

RELEVANT CLUSTER	POSSIBLE COMPLEMENTARITIES
1. HEALTH	Clinical and biomedical applications. Stronger linking of manufacturing technologies so they can push high-quality, competitive healthcare. High-performance computing in health and, in particular, brain health.
2. CULTURE, CREATIVITY AND INCLUSIVE SOCIETY	Emphasis on synergies between manufacturing and creativity. Also, software engineering paradigms for software security and interoperability, as well as ensuring bias-free approaches in AI and related digital technologies. Digital resources (including virtual worlds, 3D data protection and data systems) and ageing societies.
4. CIVIL SECURITY FOR SOCIETY	Space in the field of security (communication, navigation, Earth observation, cybersecurity). Synergies in AI and robotics: misuse (malicious use) of technologies should be emphasised.
5. CLIMATE, ENERGY AND MOBILITY	Space in all areas (climate, energy and mobility). Photonics for renewable energy. Stronger linking of manufacturing technologies so these can more directly contribute to the transformation towards a circular and clean economy. Digital optimisation of energy grids; digital enablers for energy and mobility solutions; software-defined vehicles. Zero-pollution ambition. The role of advanced materials.
6. FOOD, BIOECONOMY, NATURAL RESOURCES, AGRICULTURE AND ENVIRONMENT	Space in the areas of environmental observations, agriculture and environment. Photonics, robotics and AI for agriculture (including sustainable farming, food quality control). Data technologies or transparency and traceability of food supply chain. Stronger linking of manufacturing technologies so these can more directly contribute to the transformation towards a circular and clean economy, ensuring the removal of pollution from the source and that no harm is caused to biodiversity and ecosystems. Uptake of Save and Sustainable by Design framework. Zero-pollution ambition.

CLUSTER IMPACT SUMMARY

Cluster 5

CLIMATE, ENERGY & MOBILITY

The overarching driver for this cluster is to achieve a fair transition to climate neutrality and build resilience in the EU by 2050. It entails the transition to low, zero and negative emissions technologies and systems in the energy and mobility sectors by 2050 at the latest, while boosting their competitiveness and benefit for users and civil society and reducing their environmental footprint. Mindful of the latest findings of the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), actions will support the science-based implementation of the Paris Agreement, and contribute to EU policy priorities in the areas of climate, energy, and mobility (e.g. the European Climate Law, European Green Deal, Fit for 55 package, REPowerEU, EU Strategy on Adaptation to Climate Change, European Skills Agenda, Europe's Digital Decade, Digitalising the energy system – EU action plan, Circular Economy action plan, zero-pollution action plan, Sustainable and Smart Mobility Strategy, Net-Zero Industry Act, Critical Raw Materials Act, and long-term vision for EU's rural areas).

In addition to the European Green Deal, Cluster 5 will also contribute to the Commission priorities A Europe fit for the digital age and An economy that works for the people by generating innovation-based and inclusive growth, creating quality green jobs, and accelerating economic and social transformation and digitalisation. Becoming a leading player in fast-expanding global markets for sustainable technologies and services is imperative for the competitiveness of the European economy and the energy and transport sectors in particular.

Many challenges in the energy and transport sectors are closely interlinked and must be addressed in a holistic, inclusive and mission-driven approach. This includes their implications for citizens and society, where social sciences and humanities can play an important role, including through Europe's Cultural and Creative Industries. In addition to technological solutions, it is essential to address human, social (including the gender dimension), and societal readiness aspects for maximising societal, environmental, climate and economic benefits. In this regard, R&I actions will prioritise co-creation and social innovation approaches to address data sharing and privacy concerns, better comprehend and integrate the diverse needs of citizens and users, and promote skills development to meet future labour demands.

Given the scale of the challenges addressed by Cluster 5 as well as the multitude of complementing initiatives at various levels, it will be crucial to exploit synergies between relevant Horizon Europe partnerships, clusters, missions, and pillars and also other EU programmes and activities at national (e.g. through the Strategic Energy Technology Plan) or international level along the value chain.

HOW WILL CLUSTER 5 OF HORIZON EUROPE MAKE A DIFFERENCE?

Expected impacts

21. Advancing science for a fair transition to a climate-neutral and resilient society

Advancing climate science and creating a knowledge base to underpin actionable solutions remain essential to catalyse the global transition to a climate-neutral and climate-resilient society.

Addressing the challenges outlined in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change[92] will involve research that furthers the understanding and scientific knowledge base of the changing climate and its implications. Research will contribute to closing major knowledge gaps, and developing tools to support decision-makers in designing and implementing effective mitigation and adaptation actions at various time and spatial scales while properly accounting for synergies and trade-offs with other policy objectives. Progress is necessary in evaluating the impact of climate change on society and nature to inform the response options. Tailored scientific approaches that take into account disparities between regions and countries are needed, to understand how they are affected by global warming and what array of response options is available to them. Artificial intelligence solutions can be used to accelerate research in these crucial topics.

- The first objective is to accelerate climate action globally (both mitigation and adaptation) by:
  - improving the knowledge of the Earth system, its past evolution and future responses under different global emissions pathways and socio-economic scenarios;
  - increasing understanding of the impacts of climate change on human and natural systems, including from compound, cascading and tail risks, improving the attribution to anthropogenic factors, and leveraging the role of climate services for effective response strategies;
  - designing and evaluating solutions and pathways for climate-resilient, low-emission development to enable social transformation while promoting involvement by stakeholders and the public, climate literacy and integration of natural and social sciences; and
  - fostering synergies with the EU Mission 'adaptation to climate change' by generating actionable knowledge in support of transformative adaptation.
- The second objective is to close key knowledge gaps related to climate change by contributing substantially to key international assessments such as the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and other initiatives such as the Coupled Model Intercomparison Project under the World Climate Research Programme.
- The third objective is to strengthen the European Research Area on climate change by

92. AR6 Synthesis Report: Climate Change 2023 (ipcc.ch)

boosting scientific excellence and capacity in an inclusive manner across the participating countries.

- The fourth objective is to maximise synergies with other policy priorities such as biodiversity and ecosystem restoration, just transition, just resilience, pollution reduction, resource conservation and other Sustainable Development Goals by exploring co-benefits, trade-offs and potential unintended consequences of climate strategies and policy interventions.

22. Facilitating the clean and sustainable transition of the energy and transport sectors towards climate neutrality through cross-cutting solutions

R&I activities will develop more performant, safe, affordable, sustainable, and circular battery technologies and other storage solutions according to sectoral needs. This will cover mobility sectors (land, water and air) where next generation batteries that go beyond the current Li-ion solution can propel the EU to the global forefront. It will also cover stationary storage applications, where new large-scale and high-capacity solutions, such as flow batteries or alternative chemistries, can have a fundamental role in the development of resilient energy grids. Supporting local and sustainable battery production capacity (including equipment and skills development) will be an important driver to secure European independence. Nevertheless, R&I will also focus on second life, replacement, recycling and life-cycle management of batteries and raw materials recovery (including from electric motors) and on reducing social and environmental impacts across the life cycle and value chain.

Cities will play a pivotal role in achieving climate neutrality by 2050 and they contribute to the zero-pollution ambition. Cluster 5 will continue to support the Driving Urban Transitions Partnership[93] with the aim of increasing overall sustainability, and energy and resource efficiency of cities, as well as their climate resilience and neutrality. The EU Missions 'climate-neutral and smart cities' and 'adaptation to climate change' – for which R&I actions are detailed in the corresponding mission-specific parts of the work programme – will complement these actions and both will contribute to increasing their attractiveness to businesses and the public in a holistic fashion.

Emerging and breakthrough technologies with a high potential for achieving climate neutrality and less pollution in the energy and transport sectors may also be supported (including negative emissions technologies).

93. Driving urban transitions - the DUT Partnership.

23. Ensuring more efficient, sustainable, secure, and competitive renewable and decarbonised energy supply

R&I actions will support the just energy transition through new solutions for smart energy systems based on renewable energy and decarbonisation solutions. This will rely on clean, sustainable, and climate-resilient solutions to make the energy system and supply more reliable and secure, enhance the competitiveness of the European value chain, reduce pressure on resources (also by making technologies 'circular by design') and decrease dependencies.

R&I activities are needed on renewable energy generation from e.g. solar, wind, geothermal, ocean, hydropower, and sustainable energy vectors like biomethane, advanced biofuels, solar and synthetic renewable fuels, other. Other strategic technologies mentioned in the Net-Zero Industry Act (NZIA), as for instances heat pumps, should be covered as well.

In addition, unconventional renewable energy technologies. are needed to achieve and eventually maintain the autonomy and competitiveness of the EU energy supply. This should happen without harming ecosystems, by contributing to the zero-pollution and climate neutrality ambition of the European Green Deal and bringing social benefits for all. Actions will be supported by the use of EU space data and related services.

Furthermore, R&I activities are needed to underpin the modernisation of energy networks, markets and services, support the integration of the renewable energy system, and accelerate electrification and digitalisation. Demand-side response and innovative and cost-effective energy storage solutions at various timescales, that provide flexibility to the energy system and that minimise the use of critical raw materials and ensure, to the best extent possible, their reuse and recycling, are key elements of the energy system. R&I actions will advance their technological readiness for industrial-scale (including grid-forming) and domestic applications. It is important to address the possibilities for industry and the general public to swiftly embrace such a transition in a societal acceptable and affordable manner.

R&I actions will accelerate the research and deployment of carbon capture, utilisation and storage in electricity generation, in industry applications and greenhouse gas removal technologies. These actions will reduce the EU's dependency on imported fossil fuels and increase energy security, while reducing the energy system's vulnerability to the impacts of the changing climate. They will also balance the carbon capture, utilisation and storage chain with respect to geological storage. Where relevant, R&I actions will furthermore address the socioeconomic aspects of energy supply and will investigate emerging needs and policy in international R&I collaborations in this area.

24. Using energy in buildings and industry in an efficient, affordable and sustainable way

Together with the switch from fossil to renewable energy sources, fostering energy demand-side solutions and improving energy and resource efficiency are among the most cost-effective ways to support climate neutrality. They also create inclusive development and employment in the EU ('energy efficiency first' is a key pillar of the EU's energy policy), while contributing to better energy supply management, a reduction of environmental impacts such as pollution and import dependency, both for energy and raw materials.

Buildings, responsible for around 50% of EU energy demand when considering their full life cycle, are pivotal to the success of the energy transition and to the achievement of a climate-neutral economy. The current societal and energy-related contexts call for affordable, user-centric, more integrated, smart-ready, flexible, safe, and resilient buildings, enabling higher adaptability to needs and challenges, while responding to the increased ambitions of EU policies.

R&I actions will facilitate affordable, cost-effective and resource-efficient energy renovation to foster energy savings, with reliable performance measurement, modelling and validation. The promoted approaches, technologies and techniques should have the least environmental impacts, a focus on circularity, and materials with a low-carbon impact, thereby delivering increased life-cycle resource efficiency, security, better health, quality of life and comfort for users.

The integration of renewable sources, including thermal, and decarbonisation of heating and cooling at building and district levels will also be pursued, redirecting expenditures from fossil fuels to greenhouse gas and air pollutant reduction measures and increased resilience to the impacts of climate change and disasters. R&I is needed to achieve the electrification of technical building systems with the integration of grid-compatible, digital, secure, and flexible solutions that involve demand-response management, energy sharing and storage, and electric vehicle charging, thus maximising self-consumption of on-site renewables. Synergetic interactions of buildings with the energy system and their multi-level urban and rural environment should be improved, contributing to an integrated and flexible use of available assets and resources for a resilient operation, while contributing to the deployment of multimodal and user-centred, zero-emission mobility.

R&I should also address behavioural aspects and go hand in hand with social innovation, affordability, inclusiveness and user centricity, promoting solutions that go beyond functionality, while achieving efficiency, sufficiency and sustainability of the built environment. Reducing the overall demand for new materials in construction and renovation will be important in this context. This entails inter alia strengthening bottom-up approaches and ensuring synergies with the Built4People Partnership and the New European Bauhaus Facility.

As regards industry, efficient use of renewable energy should be optimised at all levels, with a focus on the integration of renewable electrical and/or thermal energy sources with low or no emissions of greenhouse gases and air pollutants. It should also address the recovery, storage, upgrade (e.g. with high-temperature heat pumps) and optimisation of energy flows across integrated industrial installations and the wider energy system, while ensuring physical and cyber security. It should be noted that the bulk of R&I support related to energy-intensive industries is in Cluster 4 'Digital, Industry and Space', covering industry-related topics and complementing Cluster 5.

25. Achieving sustainable, inclusive, and competitive transport modes

Transport is the only sector where greenhouse gas emissions have increased in the past three decades, rising by 33.5% between 1990 and 2019. The transport sector is responsible for 23% of CO2 emissions in the EU (of which over 70% comes from road transport) and remains dependent on oil for 92% of its energy demand. This sector is also one of the main causes of air pollution and noise and is a major source of water pollution. Greater R&I activities are needed, across all transport modes and in line with societal needs and preferences, for the EU to reach its policy goals towards net-zero greenhouse gas emissions, to significantly reduce air pollutants and noise towards the zero-pollution ambition, and to support and accelerate positive developments. Electrification of all modes of transport plays a key role in this process, and a rapid deployment of the European battery value chain is a major priority to achieve this aim.

As regards road transport, R&I actions, in particular from the related Cluster 5 partnerships, will contribute to the shift to zero-emission mobility (greenhouse gases, noise and air pollutants), ensuring that the EU remains the world leader in innovation, manufacturing and services in relation to road transport. R&I will target cost- and energy-efficient zero tailpipe emission vehicles (from two-wheeler to heavy-duty), smart, user-centric and cost-effective static and dynamic charging infrastructure, and the integration of these vehicles into a resilient mobility system and in the renewable, smart energy grid.

Aviation is a strategic sector for the EU and aims at climate neutrality by 2050 with very ambitious technology bricks, which include hybridisation, energy efficiency improvements, and 100% use of sustainable aviation fuels and (partially) electrified or hydrogen-powered, zero-emission commercial aircraft and infrastructure by 2035. R&I actions on aviation will develop enabling and integrated aircraft technologies for deep decarbonisation transformation, reducing all negative aviation impacts and greenhouse gas emissions (including noise and air pollutants), while strengthening Europe's aero-industry collaboration and industrial leadership position.

For waterborne transport, R&I actions will further advance development and demonstration of solutions in the shipping sector by 2030 that are of net-zero emissions and zero pollution (including from cargo), aiming at climate neutrality by 2050. This will be by improving

its system efficiency, safety and security, and enhancing digitalisation, automation and connectivity, including EU satellite navigation solutions. R&I actions will also advance and demonstrate on environmental problems associated with waterborne transport. All the above-mentioned solutions will overall contribute to improving the competitiveness of the sector and to the energy transition in specific sectors such as fisheries and aquaculture.

More R&I is needed to achieve a more attractive, user-friendly, competitive, affordable, easy to maintain, efficient and sustainable European rail system, integrated into the wider mobility system. R&I actions on rail transport are covered by Europe's Rail JU and as such are not part of the strategic plan for Cluster 5. Furthermore, R&I actions will implement more effective ways of monitoring and reducing air and noise pollution from transport to mitigate the overall negative impact of transport emissions on both the environment and human health.

26. Developing multimodal systems and services for climate-neutral, smart, inclusive, and safe mobility

R&I initiatives are needed to prepare the transformation of supply-based transport to demand-driven, multimodal, safe, secure, climate-neutral, and sustainable mobility and transport services for passengers and freight.

R&I will support the development of emerging digital technologies, vehicle-to-infrastructure/vehicle-to-vehicle communication, advanced satellite navigation and connectivity services and automation, together with the integration of smart charging solutions. R&I will address solutions for innovative, affordable, accessible, user-oriented, safe and inclusive services for mobility, better traffic management across the entire transport network (including the logistic dimension), and the switch from a modal/driver-centred to a multimodal/mobility-user-oriented and demand-driven approach, making use of public transport, shared mobility as well as soft/active mobility solutions, thereby reducing the climate and environmental footprint while increasing safety. In this highly data-driven context, R&I will improve the availability, access and exchange of data. Real-time data, in particular, is essential as it improves the efficiency and quality of services.

R&I actions will leverage cooperative, connected, and automated vehicles and mobility systems, improving their safety and security. Extending the system domains beyond the vehicle through connectivity makes cybersecurity a fundamental building block for trusted (digital) interaction between users, the infrastructure, and cloud-based solutions/services.

R&I will support the greening and digitalisation of freight transport and logistics operations by developing zero-emission, safe smart, energy-efficient and multimodal freight solutions to increase efficiency and improve interconnectivity, for long-haul, urban, peri-urban and rural mobility.

The EU's ageing transport infrastructure also needs to be prepared for enabling cleaner and smarter operations. Moreover, it is important to strengthen the resilience of transport infrastructure to climate change impacts, by increasing its adaptation capacity and its efficiency, and reducing its vulnerabilities.

To reach the ambitious long-term goal on improving transport safety (e.g. 'Vision Zero' for road transport), R&I actions will also focus on improving safety management, infrastructure, and user behaviour across various modes of transport.

Table 9 Overview of R&I expected impacts, intervention areas, and Horizon Europe partnerships

EXPECTED IMPACT	INTERVENTION AREAS	EUROPEAN PARTNERSHIPS*
21. Advancing science for a fair transition to a climate-neutral and resilient society	1. Climate science and solutions	
22. Facilitating the clean and sustainable transition of the energy and transport sectors towards climate neutrality through cross-cutting solutions	5. Communities and cities 9. Energy storage	Batteries: Towards a competitive European industrial battery value chain (Batt4EU) Driving urban transitions to a sustainable future (DUT)
23. Ensuring more efficient, sustainable, secure, and competitive renewable and decarbonised energy supply	2. Energy supply 3. Energy systems and grids 9. Energy storage	Clean energy transition (CET) Solar Photovoltaics
24. Using energy in buildings and industry in an efficient, affordable and sustainable way	4. Buildings and industrial facilities in energy transition 9. Energy storage	People-centric sustainable built environment (Built4People)
25. Achieving sustainable, inclusive, and competitive transport modes	3. Energy systems and grids 6. Industrial competitiveness in transport 7. Clean, safe and accessible transport and mobility 8. Smart mobility 9. Energy storage	Towards zero-emission road transport (2ZERO) Zero-emission Waterborne Transport (ZEWT) Built4People
26. Developing multimodal systems and services for climate-neutral, smart, inclusive, and safe mobility	6. Industrial competitiveness in transport 7. Clean, safe and accessible transport and mobility 8. Smart mobility	Connected and automated mobility (CCAM)

In the table, partnerships are indicated for one impact even if some of them contribute to several impacts.

INTERNATIONAL COOPERATION

The EU intends to play an increasingly leading role in global/multilateral initiatives and/or organisations (e.g. Mission Innovation, Clean Energy Ministerial, the International Energy Agency, the International Renewable Energy Agency, United Nations' agencies such as the International Civil Aviation Organization, International Maritime Organization, World Meteorological Organization, Biodiversity Strategy, and the Kunming-Montreal Global Biodiversity Framework). The EU will also maintain a strong technological collaboration in critical R&I areas of common interest for the EU and non-EU countries. Mission Innovation is the key forum for the Commission to globally stimulate action and investment in research, development, and demonstration to make clean energy affordable, attractive, and accessible for all. The Commission will continue to play a key leadership role in Mission Innovation, which is currently reflected in the co-leadership of two Mission Innovation's missions (Clean Hydrogen and Urban Transitions), its commitment in and contribution to the Mission Innovation secretariat and the delivery of the Vice-Chair of the Mission Innovation Steering Committee. Moreover, the EU plans to develop its bilateral/multilateral and regional/multiregional R&I cooperation with strategic partners who can positively contribute to excellence in R&I to address common challenges, or who represent promising fields for exchanges on advanced European technologies.

In the area of climate science, multilateral initiatives will be favoured reflecting the globalised nature of activities in this domain. R&I actions will contribute substantially to key international assessments, such as those of the Intergovernmental Panel on Climate Change and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Multilateral initiatives will be complemented exceptionally by focused cooperation at regional and national levels when these are reciprocal and of added value to the multilateral approach. Particular attention will be paid to international cooperation with high potential to support countries in implementing effective climate and environmental strategies in line with their commitments under the Paris Agreement and other schemes, in particular in developing countries and vulnerable regions.

The EU will also cooperate with international partners on innovative solutions for resource-efficient passenger and freight transport that respects the environment and human health. This includes integrated, safe, and inclusive mobility solutions for urban agglomerations that will accelerate the transition to climate neutrality. Moreover, the EU will strengthen international cooperation in several other areas of transport research, for instance in aviation, maritime shipping, inland waterway transport, road safety and connected and automated mobility, where the different regions can benefit from exchanges of research experience, develop common standards, and harmonise developments at a global level.

The EU plans to develop further the AU-EU Research and Innovation Partnership on Climate Change and Sustainable Energy, emanating from the AU-EU High-level Policy Dialogue

('Africa initiative'), to implement the AU-EU Innovation Agenda[94] adopted in July 2023, to continue cooperation on research and innovation with its neighbour countries, in particular within the framework of the Union for the Mediterranean ('Mediterranean initiative'), and with strategic and like-minded partners in the Americas (including the new EU-Latin America and the Caribbean initiative currently under preparation) and Asia, in the framework of its energy, transport and research and innovation dialogues, and connectivity partnerships.

Synergies with other EU funding programmes

Many efforts have been made into identifying and exploiting synergies with other EU funding programmes, of which the following may have the most direct links with Cluster 5.

- The **Innovation Fund** can provide sequential downstream funding for innovative low-carbon technologies in energy and transport (of which many are in the scope of Cluster 5), thereby accelerating the commercialisation and deployment of R&I results. This can build on ongoing synergy activities, for instance facilitating future applications of relevant Cluster 5 projects to the Innovation Fund, organisation of workshops for informing mature R&I projects about funding opportunities under the Innovation Fund, and the funding of dedicated synergy work programme topics. It is expected that the activities to foster synergies with the Innovation Fund already carried out in 2021-2024 will continue into the second half of the programme (covering 2025-2027) and be fine-tuned as necessary to further increase their effectiveness.
- The **Connecting Europe Facility** may also offer opportunities for funding the deployment of innovative solutions developed in the EU R&I framework programmes (and in particular, the necessary infrastructure for enabling their roll-out), in the areas of transport and energy. Building on existing successful cross-fertilisation between the Horizon Europe framework programme and the Connecting Europe Facility (e.g. as regards hydrogen applications in the mobility sector, alternative fuels infrastructure, adaptation of transport infrastructure to climate change, intelligent road transport, logistics, urban mobility/nodes and smart grids), Cluster 5 intends to further increase synergies, for instance by organising targeted events for raising awareness of programme activities or by aligning Horizon Europe work programmes and the Connecting Europe Facility, so that deployment of innovative mobility solutions can be supported.
- The **LIFE programme** facilitates sequential downstream funding of innovations by granting bonus points in the evaluation when proposals directly use results of Horizon-funded projects. LIFE's subprogrammes (notably on clean energy transition and on climate change mitigation and adaptation) contribute to the same objectives as Cluster 5 activities – i.e. the European Green Deal, REPowerEU and the zero-pollution policy framework: both address market uptake, policy support and capacity building and aim at facilitating the deployment of innovative solutions. Existing complementarities between the programmes will be strengthened, for example by reducing market barriers for the roll-out of innovative solutions (also based on knowledge from Horizon 2020 projects).

94. One of the flagship initiatives of the Global Gateway, which will in particular support the implementation of short-, mid- and long-term actions in the area of green transition related to climate change.

These three programmes are led by Cluster 5 co-chairing Commission services and implemented by the European Climate, Infrastructure and Environment Executive Agency (CINEA). Tangible and practical efforts to ensure links with those funding programmes will be strengthened and continued to ensure the highest impact.

Coordination will be further pursued with the Digital Europe Programme in the context of Earth System Science, Earth Observations, digital twins, vehicle connectivity under the connected and automated mobility domain, data technologies and artificial intelligence and related service developments, including Copernicus services that can support climate science applications. Furthermore, R&I actions in Cluster 5 contributing to the Earth System Science Initiative, under the supervision of the European Commission and the European Space Agency, will promote synergistic opportunities between space and ground-based observations, and also models to expand the fundamental understanding of the planet, its processes, and interactions with human activities.

In addition, the EU Space Programme offers data and services from the various components (Galileo, the European Geostationary Navigation Overlay Service [EGNOS], Copernicus, Infrastructure for Resilience, Interconnectivity and Security by Satellite [IRIS2]) that become relevant for many of the solutions researched under Cluster 5 (e.g. connected and automated mobility).

In 2025, Cluster 5 will continue its support for the partnership with **Breakthrough Energy Catalyst**[95], which is implemented by the European Investment Bank under the InvestEU programme.

Moreover, linkages in place with the Cohesion Policy funds will be continued. Although these funds are managed in shared management with Member States, stronger coordination mechanisms could be considered to align EU and national agendas, ensuring complementarity of actions and avoiding overlaps.

Synergies with the **Neighbourhood, Development and International Cooperation Instrument – Global Europe instrument for the Southern and Eastern Neighbourhood** and the **Instrument for Pre-Accession** will also be explored.

Finally, the strategic plan will take into account the Prague Declaration on Synergies in the Research and Innovation Funding in Europe.

95. Subject to approval by the relevant Programme Committee configurations and progress in terms of impact.

Cross-cluster complementarities

Table 10 Overview of Cross Cluster Complementarities

RELEVANT CLUSTER	POSSIBLE COMPLEMENTARITIES
1. HEALTH	Nexus health-climate change and health-pollution, and health-active mobility. Health & safety in transport and buildings.
2. CULTURE, CREATIVITY AND INCLUSIVE SOCIETY	Empowering citizens to engage in the transformation to a climate-neutral and resilient society. Promoting a just transition through effective pathways and responses to climate change and behavioural transformations, taking into account the existing socio-economic and gender-related vulnerabilities, inequalities, divergences and risks. Nexus climate change adaptation and cultural heritage.
3. CIVIL SECURITY FOR SOCIETY	Climate science and adaptation strategies for better informed decisions on disaster risk management and the climate change-security nexus. Protection of critical energy and mobility infrastructure enhancing their resilience and robustness. Innovations in energy and mobility rely on secure digital technologies and handling of data.
4. DIGITAL, INDUSTRY AND SPACE	Manufacturing technologies for energy systems, transport vehicles and infrastructure. Carbon capture and utilisation-technologies Role of industrial hubs as players in the energy system and in decarbonising society. Advances in 'safe and sustainable by design' materials and provision of suitable raw materials are key prerequisites for advances in energy and transport technologies. Many innovations in energy, mobility and climate services rely on advances in digital and space technologies, e.g. space data and services, new materials, and new energy-efficient industrial/ manufacturing processes. Key digital and chips technologies for providing better automation of transport vehicles and connection of mobility systems. Advances in interactive digital twins are key to improve the effectiveness of adaptation and mitigation measures. Climate-neutral and resilient industries. Space-based technologies, infrastructures and services are crucial for improving climate, efficiency of mobility, and energy solutions. Common critical technologies and equipment in space and aviation.

6. FOOD, BIOECONOMY, NATURAL RESOURCES, AGRICULTURE AND ENVIRONMENT	Knowledge on the role and capacity of ecosystems as carbon sinks, as a solution for adaptation as well as on impacts of climate change on biodiversity, ecosystems, and their services e.g. nature-based solutions. Climate-energy-land-food-water-biodiversity, transport infrastructure nexus. Climate-ocean-cryosphere-polar (science) nexus. Development of offshore renewable energy in full compliance with the 'do not harm' principle to the marine environment. Use of biomass for producing sustainable and less polluting bioenergy. Circularity for improving overall energy and resources efficiency. Efficiency (including energy recovery) and flexibility of plants and systems in urban water cycles. Sustainable and affordable mobility of persons and goods in rural areas, among rural areas, and between rural and urban areas. Energy efficiency and production in rural areas. Land use in rural areas.

CLUSTER IMPACT SUMMARY

Cluster 6

FOOD, BIOECONOMY, NATURAL RESOURCES, AGRICULTURE & ENVIRONMENT

CLUSTER IMPACT SUMMARY

R&I in Cluster 6 is one of the key enablers to developing, demonstrating and upscaling the solutions needed to navigate the necessary transitions to a sustainable future underpinned by the European Green Deal. Cluster 6 supports the ambition of Europe to become the first climate-neutral and climate-resilient continent by 2050, taking into account the current political, legal and economic context, with a long-term vision for a greener, fairer, more resilient society ensuring that no person or place is left behind.

Cluster 6 contributes to achieving the goals of the Paris Agreement on climate change and of the Kunming-Montreal Global Biodiversity Framework. Cluster 6 is crucial for achieving the ambitions of the European Green Deal, contributing to the dimensions outlined below and their related policies. The implementation of unifying approaches through R&I, including the One Health approach, is fundamental for Cluster 6 to deliver impactful results. The development of sustainable agriculture and food systems is one of the key priority areas of action for the EU. Cluster 6 will support R&I needs related to the Farm to Fork Strategy (including related initiatives), the common agricultural policy, the common fisheries policy, and the EU action plan on the development of organic production. Addressing R&I gaps will further contribute to laying the groundwork for systemic changes towards sustainable agricultural value chains that over time will deliver greater environmental, social and economic benefits to and from agriculture, forestry and rural areas, the fisheries and aquaculture sectors, and coastal areas as well as to food systems, both in the EU and globally. Moreover, the surge in global commodity and input prices, further accelerated by Russia's war of aggression against Ukraine, highlighted that food and nutrition security in the EU cannot be taken for granted. Agriculture, fisheries and aquaculture, food and feed systems and related industries need to become more resilient, circular and resource efficient. Therefore, fostering sustainable farming approaches, including organic farming and agroecology, sustainable aquaculture and sustainable food and feed systems becomes more relevant than ever to ensure food and nutrition security also in the long term. R&I will contribute to ensuring that food systems are healthy and safe for all. Fostering a dietary shift ensuring sustainable food consumption and reducing food loss and waste will also be key. A balanced, sustainable and inclusive development of rural and coastal areas will be essential to ensure food and nutrition security and the livelihoods of the rural population, in support of the long-term vision for the EU's rural areas.

With its strong focus on **biodiversity and ecosystems**, Cluster 6 will address the loss of biodiversity by supporting the EU biodiversity strategy for 2030, notably the proposal for a nature restoration law, the EU soil strategy for 2030, the proposal for a directive on soil monitoring and resilience, the EU forest strategy for 2030, and the EU action plan on protecting and restoring marine ecosystems for sustainable and resilient fisheries. R&I is needed to better understand and address the drivers of biodiversity loss in a rapidly changing environment, as well as to protect and restore nature and to tackle deforestation. In line

with the EU Deforestation Regulation new data, knowledge and innovation will be generated for transition to sustainable and deforestation-free supply chains. Cluster 6 will facilitate the implementation of new due diligence legislation with links to environment and achieve greater sustainability in value chains with the help of R&I.

R&I will also provide forward-looking options on transformative change for biodiversity. Cluster 6 is expected to substantially contribute to achieving the target of dedicating 10% of the Horizon Europe budget to biodiversity and ecosystems objectives, including by mainstreaming nature-based solutions and increasing agrobiodiversity. The acceleration of global crises calls for accelerating the transition towards a sustainable, climate-neutral, clean and competitive economy, for which the scaling-up of **circular economy and bioeconomy** is needed. This transition, including its social dimension, will be addressed in a holistic and systemic manner, taking into account the role of norms and values to foster behavioural change and sustainable production and consumption practices. Innovative and sustainable solutions that do not harm biodiversity and respect planetary boundaries will be sought. Cluster 6 will thus support the EU circular economy action plan, the Eco-design for Sustainable Products Regulation, the sustainable products initiative, and the EU bioeconomy strategy. It will help support thriving ecosystems, sustainable agriculture and healthy food, as well as clean air, soil, and fresh and marine water for all through quality and resource management, by addressing the sources of pollution and removing pollution in various sectors, as required by the EU action plan towards zero pollution for air, water and soil and the EU's chemicals strategy for sustainability. This will provide novel, environmentally friendly and competitive products and processes that will play a role in making the transition socially and economically sustainable by opening up new opportunities for the industry, communities and for society as a whole, also promoted by Europe's cultural and creative industries.

Cluster 6 will also support research addressing the water-climate-biodiversity-pollution-people nexus holistically and systemically in light of interconnections and interdependencies at EU and global level. This will further the understanding of the fundamental interrelationship between inland waters, the land-sea continuum, the ocean, climate change, biodiversity and human activities, and help enhance water resilience and ensure the protection of the most vulnerable regions and ecosystems. Environmental observations and modelling will need to be improved and interlinked to better understand the changes happening in the ocean, inland waters, the atmosphere, forests, soils, and other terrestrial ecosystems, to increase the resilience of ecosystems and the economy and raise public awareness about the climate, biodiversity and pollution crises. Better understanding and strengthening the complementarities and synergies between mitigation and adaptation measures to address climate change and air pollution will be important as well as developing technologies for the sustainable use of natural resources while delivering products and services to the general public. The activities of the cluster will continue to identify co-benefits with the New European Bauhaus Facility. Synergies and complementarities between Cluster 6 and the Horizon Europe Missions 'A Soil Deal for Europe', 'Restore Our Ocean and Waters', 'Adaptation to Climate

Change' and 'Climate-Neutral and Smart Cities' and with European Partnerships will be further pursued and strengthened. Cluster 6 has a strong focus on **societal transformation** that requires a holistic approach and people's involvement. Social sciences and humanities will play a crucial role in finding appropriate solutions and developing pathways that lead to the necessary fundamental changes and will ensure that Europe's society and economy are based on fair, sustainable and circular value chains, environmental justice, gender equality and social inclusion. Citizen science will keep on proving its multiple benefits in gaining more insight into the scientific process. The multi-actor approach to programming is a strength of the cluster and will be further promoted as it has proven to be fundamental to building the bridge between R&I activities and practitioners, increasing end-user focus, and delivering more impactful solutions. Furthermore, research will focus on the dynamics of the relevant transitions.

HOW WILL CLUSTER 6 MAKE A DIFFERENCE?

Expected impacts

Cluster 6 will programme investment to achieve the below expected impacts.

27. Fostering mitigation of and adaptation to climate change in areas and sectors covered by Cluster 6

Cluster 6 contributes significantly to the objectives enshrined in the European Climate Law and the 'Fit for 55' package[96] by bringing transformative changes and increasing sustainability and efficiency in the use of natural resources on land and at sea, while maintaining food safety and security and without harming biodiversity and people. Thanks to R&I, climate adaptation and mitigation – including loss and damage – will be supported by environmental observations, by taking advantage of progress on artificial intelligence, and in accordance with climate prediction models. Ecosystem restoration activities increasing biodiversity and their coupled effect on the carbon cycle and water management will continue to be explored. Links with air pollution will also be made. The increased role of the land sector as carbon sink will be further investigated, including through carbon farming and its monitoring, reporting and verification, also including in complementarity with the Mission Soil. Marine natural carbon sinks will also be addressed, including their protection and restoration. Solutions for carbon sequestration, including technologically, socially innovative and/or nature-based solutions, will be further investigated to mitigate climate change and to strengthen climate-resilient and healthy communities. The role of sustainable farming approaches that are regenerative, with a specific focus on agroecology (including agroforestry and organic farming), and the contribution of organic aquaculture and of paludiculture as well as innovative technologies to climate mitigation and adaptation will continue to be studied. Sustainability and biodiversity co-effects of carbon removal activities in agriculture and ecosystems will be analysed and quantified in the short, medium and long term.

96. Cluster 6 also supports the revised Regulation on land use, land use change and forestry, the proposal for an EU regulation on the certification of carbon removals, and the Communication on sustainable carbon cycles.

The cluster will address the long-term resilience of agriculture, forestry, fisheries and aquaculture to challenges related to climate change. This will encompass the early detection of local impacts on these sectors and will help ensure food, nutrition and water security and preservation of ecosystems. It will translate into R&I to increase the availability and resilience of water resources and increase efficiency in their management under climate change scenarios, taking into account the soil-water nexus in complementarity with the Mission Soil. Severe droughts and their effects on ecosystems and water scarcity will be in scope for R&I on agriculture and food systems. Reducing greenhouse gas emissions from primary production to consumption will be further addressed. Further R&I on how rural and coastal areas can contribute to climate mitigation and adaptation will continue to be developed.

R&I will further the understanding of the role of the rivers, coasts, ocean, seas and polar regions in climate change mitigation and adaptation. The cluster will support scientific research on the ocean-cryosphere-climate-biodiversity nexus to better understand drivers of change in these vulnerable systems and tackle emerging threats. Activities will also contribute to ensuring water resilience. This research will also cover tipping, cumulative and cascading aspects, and bring forth knowledge, solutions and innovations in support of decision-making on climate and environmental policies that aim to preserve the integrity and healthy state of the freshwaters, ocean and polar regions.

The role of the sustainable and circular bioeconomy, including of (circular) bio-based sectors, biotechnologies and industrial solutions, will be further supported to move away from fossil resources to respect planetary boundaries, including through capture and utilisation of carbon from bio-based processes. The understanding, design replication and implementation of locally and regionally adapted bio-based and circular systemic solutions, of both technological and social nature, will be supported to address climate adaptation and mitigation.

28. Putting biodiversity on a path to recovery, and protecting and restoring ecosystems and their services

R&I is needed to better understand and address all drivers of biodiversity loss, in particular focusing on the most important ones and on accelerating or emerging ones, and on their synergetic and cumulative impacts, in both terrestrial and aquatic systems. Tackling the decline of insects to ensure the continuity of their key role in ecosystems is a priority[97]. Biodiversity observation will be further developed, taking advantage of scientific and technological developments, and the need for in situ data will be addressed while considering the need to strengthen taxonomic resources. Specific needs in soil and marine and freshwater environments, including with regard to species and habitats, will be addressed in complementarity with the EU Missions 'A Soil Deal for Europe' and 'Restore our Ocean and Waters'. The protection and restoration of ecosystems, habitats and species will require new and better knowledge and methods, duly tested, and monitored at appropriate scales, as well as leveraging societal responsiveness, including for the implementation and future

97. This includes needs identified in the communication 'A New Deal for Pollinators', COM(2023) 35, 24.1.2023.

review of the incoming EU nature restoration law, the Marine Strategy Framework Directive and other relevant commitments under the 2030 EU Biodiversity Strategy. Cost-effective conservation and restoration methods, including innovative approaches to management and financing options, will be sought. Attention will be paid to synergies with activities related to ecosystem protection and restoration and those addressing climate adaptation and/or mitigation, including with Biodiversa+, other relevant Horizon Europe Partnerships and EU Missions. R&I will aim to improve the understanding and management of critical surface and groundwater ecosystems. Improved modelling of trends and integrated scenarios for biodiversity, ecosystem services and good quality of life will be essential to reach the nature restoration objectives.

The integration of methods, policies and perspectives across realms to foster biodiversity in various, connected ecosystems will be considered. To be able to steer the transformative change called for by the EU biodiversity strategy for 2030, it is also necessary to better understand the perception of the biodiversity crisis by civil society and to develop tools to increase people's involvement, to better value the economic, social and cultural benefits that nature protection and restoration bring, and to evaluate the cost of inaction in light of the accounting of ecosystems and their services. R&I will investigate and propose alternative socio-economic models that better integrate the economic value of biodiversity and nature and that will contribute to biodiversity protection and restoration, as well as innovative market instruments, while considering opportunities offered by social innovation. R&I will also analyse the environmental, social and economic impacts of nature-based solutions and the mechanisms to scale these solutions, as part of wider R&I on the just transition to a climate-neutral and nature-positive economy. It will also provide policy-relevant evidence on the impacts of economic activities and policy incentives on biodiversity, supporting the implementation of the target to identify and phase out incentives that are harmful to biodiversity and to scale up positive incentives, under the UN Kunming-Montreal Biodiversity Framework.

R&I will analyse and address the still significant knowledge gaps on the interlinkages between health and biodiversity. R&I will continue to support and investigate biodiversity-friendly farming approaches, including agroecology and organic farming, to increase agrobiodiversity. This will underpin a sustainable and climate-resilient agriculture, help improve stakeholders' knowledge, and tackle the impact of water management and food systems on biodiversity (e.g. supporting R&I on niche, underutilised and novel crops) while maintaining food and nutrition security in the long term.

29. Achieving healthy soils and forests, as well as clean air, fresh and marine water, whilst ensuring water resilience and the transition to a clean, competitive and circular economy and sustainable bioeconomy

R&I will support the development of innovative circular, bioeconomy and nature-based solutions that foster social and technological innovation across sectors, within planetary boundaries, including by sustainably employing the potential of marine and freshwater biological resources, in line with the EU's zero-pollution ambition. Innovative and sustainable circular and bio-based materials, products, processes and value chains will be developed, replacing unsustainable ones, and leading to new approaches for waste materials and by-products, aiming at pollution avoidance and remediation, and the promotion of industrial symbiosis. R&I will be needed to upgrade and upcycle waste, increase the valorisation of secondary resources, and foster a more efficient use of bio-resources. Further support will be given to circular and zero-waste production systems with minimised land/sea use. The emergence of new business and governance models, including product service systems, sufficiency-based approaches and second-hand markets will be targeted. R&I will also support safe and sustainable product by design, including durability, reliability, reusability, upgradability, reparability, recyclability, recovery of materials (addressing environmental impacts, including carbon and environmental footprint, minimising waste generation, tackling the presence of substances of concern, including microplastics and nanoplastics), and circularity of products. Sharable and comparable datasets along the whole value chain are needed to assess progress towards the zero-pollution ambition, as well as energy and resource efficiency.

R&I will seek to better involve civil society and individuals in developing circular economy by integrating behavioural approaches, skills and training, and addressing the whole value chain and territorial measures, taking into account the gender dimension. The involvement of local and regional authorities, and EU cities in R&I projects across Europe also needs to be further facilitated under the Circular Cities and Regions Initiative. In addition, the underlying dynamics enabling a more integrative approach to designing local bioeconomies will be understood.

Moreover, there will be a focus on the sustainable management of multifunctional and biodiverse forests, including through fostering sustainable forest bioeconomy and monitoring of forests in line with the future EU forest monitoring law. R&I on blue bioeconomy will leverage marine biodiscoveries for natural products and marine biotechnology applications.

R&I on sustainable water management will continue to alleviate the pressures on superficial and groundwater bodies in the context of climate change and foster water resilience, including by taking advantage of digital solutions to address water scarcity and freshwater salinisation. R&I will foster large-scale circular systems for water and wastewater reuse, addressing pollution upstream, including the recovery of water, key nutrients and secondary

raw materials, as well as nutrients recycling and valorisation. R&I is also needed to address and monitor fresh and sea water pollution from source to sea. This will be critical to tackle the combined effects from multiple hazardous substances in line with the EU zero-pollution action plan.

On soil, research will develop further decontamination techniques in complementarity with the Mission Soil. R&I is also needed to help address the objectives in terms of air and water pollution from agriculture and other relevant sectors, including the land-sea interaction, notably following the revision of the Industrial Emissions Directive, the Ambient Air Quality Directives and EU water legislation. Environmental observation needs to be further developed to fill knowledge gaps related to zero pollution, and monitoring, reporting and verification data gaps. In this sense, R&I activities will need to be continued to develop/optimise appropriate analytical methodologies to detect and monitor emerging pollutants and pollutants of great concern, including directly at their sources, for both food and feed safety and environmental protection. In the context of new EU air quality acquis, air quality monitoring and modelling will need improved sensitivity and accuracy. The proposed partnership on Forests and Forestry for a Sustainable Future will also play an important role in achieving this expected impact.

30. Ensuring healthy food and nutrition security by making agriculture, fisheries, aquaculture and food systems sustainable, resilient, inclusive and within planetary boundaries

R&I will be a key driver in accelerating the transition to sustainable, low-ecological-footprint, healthy, safe, inclusive and resilient food systems ensuring food and nutrition security from primary production to consumption while improving the livelihoods of farmers, aquaculture producers, fishers and rural communities. Farmers will continue to be empowered with knowledge and tools through strengthened cooperation and integration of science and traditional practices to: manage land, livestock, soil, water, crops and nutrients in efficient, circular and sustainable ways minimising and removing pollution; mitigate and adapt to climate change and its impacts; and foster resilience and sustainability of crops and livestock production while making farming a professionally attractive and remunerative life choice that ensures good living conditions by combining technological and social innovation solutions. A more efficient and sustainable use of fertilisers, pesticides and antimicrobials will be fostered, leading to reducing and/or phasing out reliance on harmful products through the development of viable alternatives, including through farming practices and crop improvement and adaptation. Knowledge and tools will be further developed in co-creative processes to foster and upscale sustainable farming approaches that are regenerative with a specific focus on agroecology (including agroforestry and organic farming). This will unlock the potential to achieve the objectives set for the agricultural sector under this expected impact, including contribution to food and nutrition security while preserving and strengthening biodiversity, plant, animal and soil health, and their related ecosystem services.

Key research areas for agriculture will include mitigation of and adaptation to climate

change, fostering plant and animal breeding and conserving and improving the use of genetic resources (including the use of new technologies). Cluster 6 will also address crop diversification, improvement and adaptation, address pollution challenges for soil in complementarity with the Mission Soil, water and air, address nutrient losses, and improve biodiversity and the provision of ecosystems services. Tools and methods will be developed for the monitoring of impacts of new technologies on sustainability and resilience of the agri-food system Research activities will also aim to bolster plant health, protect animal health and welfare, foster sustainable livestock systems, and leverage the potential of protein and underutilised crops. Fish and seafood production will rely on low-impact fishing and aquatic ecosystems and resources, while monitoring tools will be essential to ensure their sustainability. Solutions will continue to be sought to reduce environmental impacts of fishing practices. Gathering knowledge and adapting fisheries and aquaculture to a changing climate and environment will be key to helping the sectors become more resilient.

R&I will further help transform food systems by making them more innovative, inclusive, digitally driven when relevant, and capable of ensuring access to a sufficient supply of affordable nutritious food and feed, including when facing crisis situations and socio-economic transitions. Further tools to decrease the environmental footprint of food systems, addressing biodiversity and pollution will be developed. In line with the Farm to Fork Strategy and Food 2030 pathways, critical leverage points for the transition towards sustainable, healthy and inclusive food systems will be tackled through R&I to foster the implementation of sustainable healthy diets, alternative protein foods, food waste reduction and valorisation, improved resource efficiency, microbiome solutions, nutrition for healthy lives, food safety and food fraud prevention, food systems in Africa, the digital transition, and zero-pollution food systems. Environmental sustainability and circularity of food systems will be addressed, taking into account interdependencies at EU and global level. Knowledge and tools will be made available to all food system stakeholders, such as farmers, aquaculture producers, processors, food service providers, and retailers, to foster their sustainability performance and contribute to biodiversity protection. Pollution and other relevant environmental health impacts from food and beverage processing industries and downstream stakeholders will be investigated. The opportunities that environmental observations and use of data might offer to enable sustainable, resilient, effective and efficient food systems could be further explored.

31. Sustainably developing rural, urban and coastal areas

Sustainable, balanced and inclusive development remains a challenge for many rural, coastal and urban areas in Europe and globally.

The ageing of the population, depopulation, gender inequalities, and the lack of services and appropriate infrastructure hinder the scaling-up of economic opportunities beyond agriculture and traditional livelihoods. R&I is needed to advance sustainable development, improve inclusive community services (e.g. health coverage compared to urban areas, educational and cultural opportunities for children and young people, lifelong learning opportunities for adults,

in particular women and people in vulnerable situations) and enable rural communities to benefit from and be an active part of the digital and green transitions. Further research will explore dynamics between locals and newcomers in rural areas and links to the urban and suburban areas. R&I will further focus on how to upscale rural-urban synergies while improving territorial governance and strengthening rural innovation ecosystems. The options of sustainable farming approaches, including organic farming and aquaculture as well as agroecology, in providing economic opportunities in rural areas, preventing rural depopulation and attracting people back to rural areas will be explored. The cluster will also keep on supporting the long-term vision for the EU's rural areas, by contributing to developing stronger, resilient, prosperous and connected rural areas and communities.

R&I will further underpin the development of resilient, inclusive, healthy and green coastal communities. In particular, this will be done by fostering the human-nature interface with regard to aquatic environments, for instance by encouraging marine citizenship and ocean connectedness, and by promoting nature-based solutions and blue-green infrastructure. Initiatives will be rolled out to support citizen science, literacy, and observation and stewardship of rivers, freshwater, and coastal and sea areas, in terms of knowledge, social processes and social innovation.

Urban and peri-urban aspects related to the specific areas of intervention of this cluster, such as the restoration of urban ecosystems, urban agriculture and food systems, will continue to be studied and developed as appropriate and in complementarity with relevant missions and partnerships.

32. Developing innovative governance models and tools enabling sustainability and resilience

R&I will provide strong evidence-informed knowledge and tools to support policy design (for public authorities, businesses and individuals) and decision-making processes (implementation, monitoring, reporting and verification for achieving the necessary transformative changes).

Environmental observations will be made more accessible and interoperable, building user-tailored, integrated products and metrics using advanced digital methodologies including AI. R&I and coordination activities for environmental observations, modelling and forecasting will support building targeted and actionable environmental knowledge and insights for policy design and evaluation, as well as a more sustainable and resilient society and economy.

R&I supporting the digital transformation of food systems and agriculture, forestry, fisheries and aquaculture sectors will increase their sustainability without harming biodiversity and the environment. Emphasis will be placed on the use of data in agriculture to drive effectiveness, efficiency and sustainability considering private and public interests. This includes fostering the sustainability performance of applied digital and data technologies. The data governance including the sharing of data will be taken into account.

Agricultural knowledge and innovation systems will be strengthened at EU/national/local levels through networks bridging the gap between science and practice, improving the understanding of the multi-actor approach, and upgrading this approach, through instruments such as living labs. Cluster 6 activities will foster research on knowledge, skills and for improving farming practices, support training and education for farmers, strengthen the important role of advisers, and foster peer-to-peer learning to support generational renewal in farming, taking into account gender equality, and extending the lifetime and excellence of demo farms and other placed-based innovation instruments.

In line with the New European Innovation Agenda, R&I will foster the establishment of regional innovation valleys for the bioeconomy and food systems. Improved governance enabling systemic change and strengthening the science-policy interface will be supported and will contribute to achieving sustainable food systems and overall sustainability goals. Bioeconomy governance will maximise synergetic effects of sectoral policies, promote more sustainable consumption patterns, and promote youth participation and societal acceptance of innovative food systems and bio-based solutions including by leveraging social innovation.

Table 11 Overview of R&I expected impacts, intervention areas, and Horizon Europe partnerships

EXPECTED IMPACT	INTERVENTION AREAS COVERED	EUROPEAN PARTNERSHIPS*
27. Fostering mitigation of and adaptation to climate change in areas and sectors covered by Cluster 6 y	**Environmental observation; biodiversity and natural resources; agriculture, forestry and rural areas; seas, oceans and inland waters; food systems; bio-based innovation systems in the EU bioeconomy; circular systems**	Water4All: Water Security for the Planet.
28. Putting biodiversity on a path to recovery, and protecting and restoring ecosystems and their services	**Environmental observation; biodiversity and natural resources; agriculture, forestry and rural areas; seas, oceans and inland waters**; food systems; bio-based innovation systems in the EU bioeconomy; circular systems	European Biodiversity Partnership (Biodiversa+)

29. Achieving healthy soils and forests, as well as clean air, fresh water and marine water, whilst ensuring water resilience and the transition to a clean, competitive and circular economy and sustainable bioeconomy	**Environmental observation**; biodiversity and natural resources; **agriculture, forestry and rural areas; seas, oceans and inland waters**; food systems; **bio-based innovation systems in the EU bioeconomy; circular systems**	Forests and Forestry for a Sustainable Future
30. Ensuring healthy food and nutrition security by making agriculture, fisheries, aquaculture and food systems sustainable, resilient, inclusive and within planetary boundaries	Environmental observation; biodiversity and natural resources; **agriculture, forestry and rural areas; seas, oceans and inland waters; food systems**; bio-based innovation systems in the EU bioeconomy; circular systems	Agro-ecology, Living Labs and Research Infrastructures Animal Health and Welfare Sustainable Food Systems for People, Planet and Climate.
31. Sustainably developing rural, urban and coastal areas	Environmental observation; biodiversity and natural resources; **agriculture, forestry and rural areas; seas, oceans and inland waters; food systems**; bio-based innovation systems in the EU bioeconomy; circular systems	
32. Developing innovative governance models and tools enabling sustainability and resilience	**Environmental observation; biodiversity and natural resources; agriculture, forestry and rural areas; seas, oceans and inland waters; food systems; bio-based innovation systems in the EU bioeconomy; circular systems**	Agriculture of Data Sustainable Blue Economy

In the table, partnerships are indicated for one impact even if some of them contribute to several impacts.

INTERNATIONAL COOPERATION

Global environmental challenges require strong global collective engagement. The EU and its Member States played a leading role in achieving the Kunming-Montreal Global Biodiversity Framework at the UN Biodiversity Conference (COP-15) (Montreal, December 2022). R&I activities in Cluster 6 will be designed around the 4 goals and 23 targets for 2030 set out in the Kunming-Montreal Global Biodiversity Framework and will include support to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). The cluster will also support the International Resource Panel as well as the objectives of the Global Soil Partnership and the European Soil Partnership in complementarity with the EU Mission 'A Soil Deal for Europe'.

The High Seas Treaty adopted by the UN Conference on Marine Biodiversity of Areas Beyond National Jurisdiction (New York, March 2023) represents another landmark achievement for ensuring the conservation and sustainable use of marine biological diversity in the high seas, also thanks to provisions on knowledge on deep-sea ecosystems and impacts from human activities. R&I activities will be developed to deliver on this Treaty by protecting the ocean, tackling environmental degradation, fighting climate change, and preventing biodiversity loss. At the same time the UN Decade of Ocean Science for Sustainable Development and the UN Decade on Ecosystem Restoration will be supported. Building on the UN Ocean Conference (Lisbon, June 2022) and the UN Water Conference (New York, March 2023), where the importance of R&I was highlighted within the EU's commitments, cooperation with international partners will be strengthened especially through the European Partnership Water4All and the EU Missions 'Restore our Ocean and Waters' and 'A Soil Deal for Europe'.

Cluster 6 will also support international action to stop and remove pollution. Notably, R&I will support multilateral action to end global plastic pollution, based on the resolution backed by the UN Environment Assembly (UNEA) in 2022 that set up an intergovernmental negotiating committee entrusted with the task to propose a draft legally binding agreement by the end of 2024. It will also support the future Science Policy Panel on chemicals, waste and pollution, which was also agreed to be set up at the UNEA in March 2022. Moreover, R&I activities will further support the achievement of the United Nations 2030 Agenda and its Sustainable Development Goals, ensure food and nutrition security, and address transboundary impacts, including by seeking participation of low and middle-income countries. Towards these ends, the sharing of data and knowledge as well as development standards and good practice will be fostered within the Group on Earth Observations. International cooperation and governance on environmental observations will be supported including by providing tools to optimise observing systems more objectively.

International cooperation will remain of critical importance for the agricultural, marine and forestry sectors, rural areas and food systems (notably in the aftermath of the UN Food Systems Summit of 2021), taking into account the current geopolitical developments. As

part of the EU-Africa Global Gateway Investment Package, and in light of the African Union EU Innovation agenda, the Africa initiative under Horizon Europe launched in 2021 will be maintained. On food systems in Africa, synergies will be sought in particular with the Food, Nutrition Security and Sustainable Agriculture (FNSSA) Partnership.

The signing of the All-Atlantic Ocean Research and Innovation Alliance Declaration in July 2022 offers a renewed strategic framework to strengthen and expand marine research cooperation in the Atlantic basin from pole to pole, creating synergies to develop shared knowledge and solutions to better understand the Atlantic Ocean and address its most pressing challenges.

R&I (including under the Sustainable Blue Economy Partnership) will support international ocean governance and sustainable blue economies as well as sustainable fisheries and aquaculture in developing economies and as part of international frameworks. Initiatives to extend knowledge and innovation concerning the Arctic will be addressed, considering research needs stemming from cooperation under international frameworks such as the Arctic Science Ministerial process.

Cooperation with international partners across sectors covered by Cluster 6 will keep on being encouraged, including as part of the Mediterranean Initiative, notably through the Partnership for Research and Innovation in the Mediterranean Area, and the new initiative between the EU, Latin America and the Caribbean that is under preparation.

The international dimension of the bioeconomy, with a focus on bio-based solutions and approaches as well as the role of biotechnology, will need further strengthening, for instance within the International Bioeconomy Forum and with Organisation for Economic Co-operation and Development partners.

Further international R&I collaboration on land use and climate change can also emerge from the participation of the Commission and several Member States in the Agriculture Innovation Mission for Climate and from other initiatives promoted under the UN Framework Convention on Climate Change.

All international activities in this cluster will be aligned with the Global Approach to Research and Innovation adopted by the Commission in 2021 to improve global cooperation in key areas to support the well-being of future generations.

SYNERGIES WITH OTHER EU FUNDING PROGRAMMES

Synergies with other EU programmes and funding instruments are crucial to maximise the impact of R&I solutions developed in Cluster 6 to help achieve European Green Deal objectives and targets.

Synergies are well established with the common agricultural policy (CAP). Knowledge and innovation arising from Horizon Europe activities are made available to farmers, foresters, rural communities and other stakeholders through, for example, thematic and advisory networks funded by Horizon Europe. These activities along with other multi-actor projects are encouraged to connect with operational groups funded under the CAP through the CAP strategic plans and the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI). The EU CAP Network supports networking by bringing together stakeholders from the European Network for Rural Development and the EIP-AGRI. In the EU CAP Network, the EIP-AGRI aims to promote networking to close the gap between research and practice. Existing synergies between Horizon Europe and the CAP will be further strengthened for R&I activities in agriculture, forestry and rural development including through the implementation of the 'multi-actor approach', place-based innovation (e.g. living labs, light houses and demo farms) and strengthened agricultural knowledge and innovation systems. Knowledge and innovation arising from Cluster 6 will continue to inform CAP developments.

The LIFE programme fully contributes to the European Green Deal with a high leverage potential of Cluster 6 R&I results. LIFE's subprogrammes target the protection of nature and biodiversity; the transition towards a circular, energy-efficient, renewable energy-based, climate-neutral and resilient economy; improvements in air quality and in the ecological status of European waters; the restoration of soils; and the reduction of hazardous chemicals. LIFE facilitates sequential downstream funding of innovations by granting bonus points in the evaluation when proposals build on or upscale the results of projects funded by other programmes, including Horizon Europe. It therefore acts as a catalyst for taking up and implementing R&I results developed in Cluster 6.

Close collaboration will be further developed with the EU Space Programme and the Digital Europe Programme in the areas of Earth observations, Earth system science, digital twins, data technologies and AI, and related service developments, including the Copernicus services. Furthermore, through the joint Earth System Science Initiative of the European Commission and the European Space Agency (ESA), R&I activities in Cluster 6 will maximise complementary roles with the ESA Future Earth Observation programme for the benefit of the scientific community and the general public, unlock the full potential of the synergistic opportunities between space- and ground-based observations, and develop models to expand the fundamental understanding of the planet, its processes and interactions with human activities. In addition, and in connection with the international cooperation initiatives, synergies with the Global Europe programme, as part of the Global Gateway, may be sought.

Future R&I activities could benefit from complementarities with projects funded by other instruments and/or gain additional support from other EU programming instruments such as the European Regional Development Fund, the European Social Fund Plus, the Just Transition Fund, the European Maritime, Fisheries and Aquaculture Fund, the European Agricultural Fund for Rural Development, DeSIRA+, CGIAR and InvestEU under indirect management, to expand the financial offering to near market technologies.

Cross-cluster complementarities

Table 12 Overview of Cross Cluster Complementarities

RELEVANT CLUSTER	POSSIBLE COMPLEMENTARITIES
1. HEALTH	Biodiversity and health, nutrition and food, One Health approach. Mental health of people living in rural or remote areas, farmers and fishers. Access to good quality health services in rural areas.
2. CULTURE, CREATIVITY AND INCLUSIVE SOCIETY	Rural and coastal socio-economic development as well as empowering people to get involved in the inclusive transformation to a climate-neutral society. Inclusive and participatory bioeconomy governance. Cultural heritage of rural communities, rural tourism.
3. CIVIL SECURITY FOR SOCIETY	Food (and feed) security and safety, and water security.
4. DIGITAL, INDUSTRY AND SPACE	Systemic transition to a digital economy, and new circular and bio-based business models across different life cycles of products and value chains. Food packaging, sustainability of food packaging materials (bio-based or recycled), quality standards. Environmental observations (e.g. crop control, fisheries control, biodiversity monitoring). Digitalisation of agriculture (e.g. digital data management to leverage remote sensing).
6.CLIMATE, ENERGY AND MOBILITY	Carbon sequestration, including through carbon farming. Environmental observation supporting climate science and research on pollution. Biodiversity-bioeconomy-energy-water nexus. Climate-ocean-cryosphere-polar science nexus. Mapping of marine and freshwater ecosystems. Synergies between renewable energy production, sustainable agricultural land management and sustainable food production.

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The second Horizon Europe strategic plan will steer research and innovation funding within and beyond Europe to tackle key global challenges such as: (i) climate change; (ii) pollution; (iii) the loss of biodiversity; (iv) the digital transition; and (v) an ageing population.

From fundamental research all the way through to breakthrough innovation and the deployment of innovative solutions, the strategic plan steers investment into the **green** and **digital transition**, building **a more resilient, competitive, democratic and inclusive Europe**.

To ensure it is fit for purpose, the strategic plan has been developed together with the Member States and Associated Countries through extensive exchanges, including a large public consultation and an event to engage the general public. The evidence for the strategic plan is based on the strategic plan analysis.

Research and Innovation policy

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