

Orientations towards the HE Strategic Plan (2021-2024)

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NON-PAPER
for preparing the
ORIENTATIONS DOCUMENT FOR
CO-DESIGN
VIA WEB OPEN CONSULTATION

CONTENTS

GENERAL ORIENTATIONS	7
KEY STRATEGIC ORIENTATIONS FOR R&I SUPPORT	21
HEALTH	22
CULTURE, CREATIVITY AND INCLUSIVE SOCIETY	ERREUR ! SIGNET NON DEFINI.
CIVIL SECURITY FOR SOCIETY	45
DIGITAL, INDUSTRY AND SPACE	53
CLIMATE, ENERGY AND MOBILITY	67
FOOD, BIOECONOMY, NATURAL RESOURCES, AGRICULTURE & ENVIRONMENT	90
RELEVANT ACTIVITIES IN PILLAR I	109
RELEVANT ACTIVITIES IN PILLAR III	109
RELEVANT ACTIVITIES IN THE 'UNDERPINNING PART'	109

Note:

The purpose of this document is to ignite and stimulate a co-design process that will lead to the preparation of the Strategic Plan.

This document is be accompanied by a questionnaire to collect, in a structured manner, the inputs from the respondents.

The co-design process will include the results of the discussions held during the European Research and Innovation Days, to be convened in Brussels on 24-25-26 September 2019, as well as other possible initiatives.

This document is not the Strategic Plan or its draft.

Reading guide and background

The purpose of this document is to stimulate a lively co-design process that will lead to the preparation of the Strategic Plan for Horizon Europe – the European Union Framework Programme for Research and Innovation 2021 – 2027 (Horizon Europe).

The Strategic Plan is intended to facilitate the implementation of Horizon Europe by acting as a “bridge” between the Horizon Europe legislative package, and the work programme, which contains the call texts and allocates budgets allowing researchers, innovators and all interested stakeholders to apply for funds.

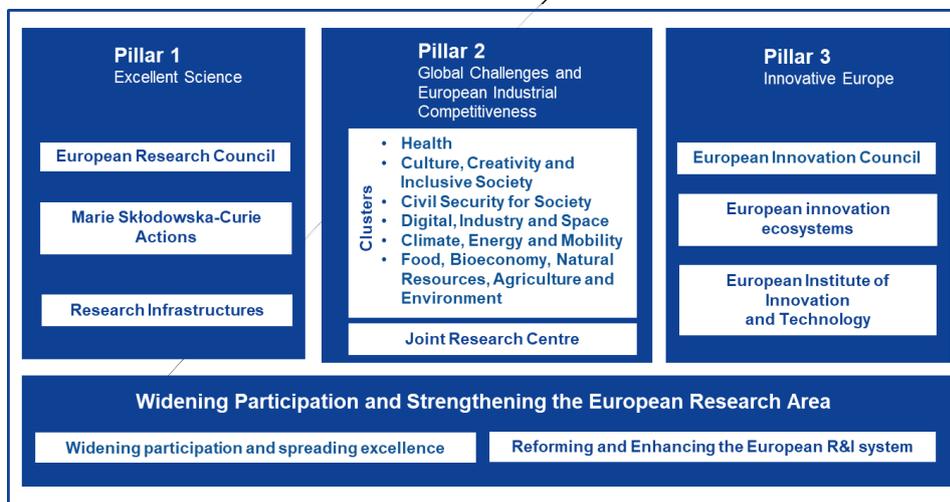
Horizon Europe is expected to be structured in three pillars, supported by activities aimed at widening participation and strengthening the European Research Area;

Pillar 1, Excellent Science, will reinforce EU scientific leadership through the European Research Council (ERC), Marie Skłodowska-Curie Actions and Research Infrastructures.

Pillar 2, Global Challenges and European Industrial Competitiveness, will take forward the societal challenges and industrial technologies to better address EU and global policy priorities (SDGs) and accelerate industrial transformation. Pillar 2 includes six broad thematic “clusters” of activities, described in figure 1.

Pillar 3, Innovative Europe, focuses on stimulating market-creating breakthroughs and ecosystems conducive to innovation, including through the new European Innovation Council.

Figure 1 - Preliminary Horizon Europe Structure



Note: Preliminary Horizon Europe Structure as agreed by Council and Parliament in March/April 2019

The structural elements of the Strategic Plan and the key in the process for defining it are set out in the Horizon Europe legislative package¹, of which significant parts have been agreed in principle by the Council and European Parliament in March and April 2019. While this document is not the Strategic Plan or its draft, attention has been given to ensure it reflects the structure and content indicated in the legislative package.

As defined in the legislative package, the Strategic Plan will focus on the second Pillar of Horizon Europe, ‘Global challenges and European industrial competitiveness’. Contributions to other operational objectives of Horizon Europe will also be included, notably those resulting from relevant activities in other Pillars and from the Widening Participation and Strengthening the European Research Area part.

The first Horizon Europe Strategic Plan will cover the years 2021 to 2024. It will be used to facilitate implementation of the programme during this period, in particular the preparation of the multi-annual work programmes. It will set out key strategic orientations for the support to research and innovation, including a description of expected impacts, cross-cluster issues and intervention areas covered, and will identify missions and European Partnerships. As such, the plan will not repeat the rationale of the Horizon Europe Specific Programme, nor the intervention logic that led to the component parts of the programme. Rather, taking the Specific Programme as a starting point, it identifies major policy drivers, the strategic priorities, and the desired impact, focussing on those elements within the Programme that should be supported during the first implementation period.

This document is based on a comprehensive set of sources, [annex to be added] and has been the subject of extensive exchanges with Member States, even at very early stages of the drafting process. It takes into account the result of an underlying analysis, as defined in the Horizon Europe legislative package.²

Given that the projects supported in the first four years of Horizon Europe will not be completed until 2030, and given the nature of research and innovation activities, the unpredictability of its results and the time needed before they produce comprehensive impacts, the planning process is considering possible futures up to the middle of this century.

¹ Consisting of 1) the Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing Horizon Europe - the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination (Framework Programme) and 2) DECISION OF THE COUNCIL on establishing the specific programme implementing Horizon Europe - the Framework Programme for Research and Innovation - Partial General Approach (the Specific Programme), as agreed by Council and Parliament in March and April 2019 . Strategic planning is dealt with especially in Article 4a of the Proposal for establishing the specific programme implementing Horizon Europe - the Framework Programme for Research and Innovation (the Specific Programme).

² As defined in Art. 4a, analysis that includes political, socio-economic and environmental drivers which are relevant for the EU and the member States’ policy priorities; the contribution of research and innovation to the realisation of the policy objectives; evidence-base resulting from foresight activities, science, technology and innovation indicators, international development such as the implementation of the Sustainable Development Goals and the measures to widening participation and sharing excellence, and participation of small and medium enterprises; priorities with the potential to be implemented in synergy with other European Union programmes; stakeholders consultation and citizen engagement; and complementarity and synergies with planning of the knowledge innovation communities of the European Institute of Innovation and Technology.

Content

This paper is divided into two main sections.

The first section, the General Orientations, will outline cross-cutting challenges and targeted impacts for the future Strategic Plan and is divided into four parts. First, the challenges currently facing the EU and the drivers that are likely to cause or exacerbate them are set out. The second part describes key EU policy objectives and responses to the challenges and it is outlined how research and innovation impacts can be targeted to enable these goals. The third and fourth parts describe key specific issues that will be taken into account during the implementation of Horizon Europe and key instruments for maximising the targeted impacts.

Following the section on general orientations, further details are given in six, cluster-specific sections, which also indicate the intervention areas for each cluster.

[Short recap of each cluster text to be inserted]

GENERAL ORIENTATIONS

1. Investing in research and innovation – shaping our future, together

With a proposed budget of 100 billion euro from 2021–2027, the Horizon Europe framework programme represents the largest collaborative multinational research and innovation investment in Europe and is open to participants worldwide. When the European Union undertakes an investment of this magnitude, it does so because research and innovation are essential for finding new solutions to the challenges we are facing – and because the challenges are of such a magnitude that they cannot be addressed by one country alone. Research and innovation create new opportunities, tackle climate change, enable sustainable economic growth, competitive businesses and industries and better public services for all Europeans. Research and innovation allows us to shape the future and the reality in which we want to live.

Whilst European research and innovation is setting a world standard for excellence, the impact of investments in research and innovation is greatest when efforts have not only a rate, but a direction. This view is reflected in particular in the overarching objectives for the research and innovation activities in the Second Pillar of Horizon Europe, “Global challenges and European Industrial Competitiveness”. These are especially to *generate knowledge, strengthen the impact of research and innovation in developing, supporting and implementing Union policies and support the access to and uptake of innovative solutions in European industry, notably in SMEs, and society to address global challenges, including climate change and the Sustainable Development Goals*³.

The future Strategic Plan for Horizon Europe will put forward the specific impacts targeted for European Union research and innovation activities, and the priorities for the first four years of implementation. The intention is thus to direct Horizon Europe investments *where it matters most*, within the overall objectives described above, supporting the achievement of key policy goals of the European Union, including the Sustainable Development Goals. Shaping our future, together.

2. The challenges and transitions we face

Europe faces a number of serious challenges⁴, where further investments and supportive measures in research and innovation are needed to create and deploy new solutions and to transform global threats into new opportunities for European businesses and societies.

In particular:

³Proposal for Framework Programme, art. 3, 2b [SDGs could be presented in an annex]

⁴ The challenges described in this section are based on extensive analysis and foresight, further described in the background document [Annex 7, to be added].

- **Climate change** brings unprecedented challenges, in a world where a rapidly growing global population, unsustainable production and consumption patterns and changing consumption patterns put the spotlight on **planetary boundaries**, with mounting pressures on ecosystems (on land and sea) and on natural resources such as soil, water, air and biodiversity. At the same time humanity will have to rely on ecosystems and nature based solutions to face those challenges;
- **Europe's industry**, itself responsible for a share of greenhouse gas emissions, pollution and waste, also **faces fierce international competition**, and barriers to international trade. Its autonomy is compromised by reliance on imported raw materials and key technologies. Meanwhile, the transition to **new technologies**, including digitisations, presents almost unfathomable possibilities for innovation, but also raises legitimate concerns about the impact on employment, the quality of jobs in the future, and the ethical and wider implications for society as a whole;
- **Changing demographics**, as European families become smaller while life expectancy increases, and large-scale movements of people within and across the boundaries of the EU create impacts – both positive and negative - on social cohesion and national budgets, including the health and social security systems;
- The European values of **respect for human dignity, freedom, democracy, equality, the rule of law and respect for human rights** are the foundations of more open, fair cohesive and inclusive societies and should guide our societies' ability to successfully govern the transition to carbon-neutrality and sustainability. But at the end of the second decade of this century we see a certain fragility in the EU model, a questioning of established institutions, and a worrying distance between perceptions and reality.

In the face of these challenges, and an uncertain geopolitical situation with evolving superpower relations, and a seemingly ever-present terrorist threat, some citizens understandably experience fear of change and strong feelings of **insecurity**.

These challenges present both threats and opportunities for Europe. Our success in responding to these pressing concerns will each time depend on the success of the transformations engaged, in order to resolve the trade-offs due to nowadays' technologies, business models and behavioural attitudes. Opportunities should not be missed; threats should not be overlooked; innovation should not be delayed.

On the one hand, incremental improvements are of great benefit (e.g. to increase our efficiency), on the other hand, more substantial and systemic changes are required for Europe to achieve sustainability, e.g. to simultaneously achieve economic, environmental and social objectives.

3. The future we want: supporting EU policy responses through Horizon Europe impacts

Research and innovation have a vital contribution to make, in tandem with other interventions, creating new solutions and fostering constant innovation, both incremental and disruptive. Horizon Europe will help determine the speed at which transitions can take place, and the rate at which European research and innovation actions succeed in developing, upscaling, implementing and commercialising such innovative solutions will steer the EU's future sustainability, prosperity, and well-being of its citizens. At its simplest, Horizon Europe, and in particular its second Pillar, will help create a future where Europe's citizens are **healthy, prosperous** and, above all, **happy**, in an **equitable world** characterised by **sustainable development**.

However, in order to maximize the potential impact of Horizon Europe investments, it is necessary to prioritise, and direct a part of the funds towards the areas where we believe they will matter the most, supporting key policy priorities of the European Union.

The Commission contribution to the Sibiu Summit on the Future of Europe sets out five recommendations for policy priorities for Europe's future strategic agenda⁵:

- 1) Protective Europe, concerning security and defence policy;
- 2) Competitive Europe, which focusses on research and innovation, new technologies, digital capacities and industrial policy;
- 3) Fair Europe, which centres on social inclusion, health, rule of law and fundamental rights;
- 4) Sustainable Europe, regarding sustainable development, climate change, circular economy and energy;
- 5) Influential Europe, dealing with international cooperation, promoting European values and standards.

Together with the Sustainable Development Goals, these abovementioned priority areas can be seen as shaping future policy responses to the challenges and transitions Europe is currently facing. For each of these priorities, European research and innovation have great potential for enabling further progress – though naturally not in equal measures across all priority areas. Indeed, European investments in research and innovation activities are in many cases already addressing challenges and supporting transitions and current policies within priority areas.

In supporting these EU policy responses through Horizon Europe, we will ensure we can build on ongoing research foundations and investments. For example, activities carried out within the FET Flagships on Graphene, the Human Brain Project and Quantum Technology, which are supported under Horizon 2020, will continue being supported under Horizon Europe through calls for proposals included in the work programmes.

⁵ https://ec.europa.eu/commission/future-europe/commissions-contribution-informal-eu27-leaders-meeting-sibiu-romania-9-may-2019_en

The impacts expected from Horizon Europe will contribute to the aforementioned five policy priorities for the future of Europe, and to the Sustainable Development Goals, as set out below.

Protective Europe

Policy objectives: While the establishment of the European Union in itself has brought unprecedented peace and prosperity over the last seven decades, there is a continued need to address terrorism and security issues, which are among the top concerns for European citizens, and to enhance internal security within and across the European Union, and along its external borders. The overarching ambition of secure societies is also reflected in Sustainable Development Goal 16, which among others, aims to achieve peace, justice and the rule of law.

There is a raft of EU policy responses to current security challenges. As regards disasters, these include the Union Civil Protection Mechanism, the EU Adaptation Strategy and the Sendai Framework for Disaster Risk Reduction (2015-2030). In the framework of the European Agenda on Security and as part of the development of a Security Union, the EU has adopted policies and instruments on integrated border management, on protection of public spaces, security of infrastructure, and fighting crime, including cybercrime and terrorism. An EU Maritime Security Action Plan addresses relevant challenges. Policies have also been put in place to ensure cybersecurity and online privacy.

Key targeted impacts: Research and innovation activities currently support the above mentioned policies in various ways. Investments in research and innovation within **civil security for society** (Cluster 3) will contribute to creating ‘*a resilient and more stable Europe that protects*’, especially by supporting the following targeted impacts:

- Improved disaster risk management and societal resilience [through....]
- Improved management of EU external borders [by...]
- Better protection of public spaces; [etc]
- Improved security and resilience of infrastructure and vital societal functions;
- Improved maritime security;
- Fighting crime and terrorism more effectively;
- Cybersecurity and a secure online environment.

Competitive Europe

Policy objectives: Research and innovation play a central role in enhancing sustainable competitiveness throughout Europe and Europe has the potential to become a world leader in digital transformations. However, there is a need to prepare our technological and industrial future in a more strategic way, including incentivising innovation and facilitating the uptake of new technologies. New developments within mobility and transport, including automated and connected mobility, will also require new solutions, still to be developed and implemented. Furthermore, the need to promote economic growth, sustainable industrialization and innovation is reflected in Sustainable Development Goals 8 and 9.

The renewed EU Industrial Policy Strategy shows how the EU must tackle missing segments in key strategic value chains⁶ if its industry is to become competitive and sustainable at the same time. This requires a stepping up of the level and quality of the EU research and innovation effort with focus on the key parts of strategic technology supply chains, which tackles missing segments in key strategic value chains: from secure and sustainable supply of raw materials, maximising the value of its resources and materials, to batteries, low-carbon industry, space critical components smart connectivity platforms. At the same time, breakthrough technologies and solutions are necessary to bring about a deep decarbonisation of EU industries by 2050, and foster a circular economy.⁷ Future factories will be carbon-neutral, resource efficient and fully integrated in the circular economy. The zero-carbon and circularity ambitions should reinforce one another.

Key targeted impacts: New and emerging technologies are a key focus area for current EU investments in research and innovation. Further investments in research and innovation regarding **digital, industry and space** (cluster 4) will especially contribute to the following targeted impacts:

- Support core technologies enabling the digitisation and transformation of EU industries, including their decarbonisation, and enhancing their global competitiveness;
- [Through development of new technologies ...] Guarantee European autonomy in terms of core technologies and resources;
- Help achieve sustainability goals in industry and society, notably in the fight against climate change and the protection of the environment [by...]

Investment in research and innovation regarding **health** (cluster 1) will support an innovative, sustainable and globally competitive health-related industry, while investments in research and innovation for **mobility and transport** (cluster 5) will contribute to developing low-carbon and competitive transport solutions across all modes.

Fair Europe

Policy objectives: The health and well-being of its people and the promotion of social inclusiveness are central aims of the European Union's policies and programmes. However, further support is needed to provide high-quality, affordable health care, including through digital transformation of the health system. With the proclamation of the European Pillar of Social Rights, the EU set the direction towards a fairer, inclusive and more social Europe for all European citizens based on a European social model that is fit for the challenges of the 21st century. It is necessary to continue to deliver on this agenda, including by continuing to address inequalities and social challenges across regions and Member States, in order to safeguard shared values and mutual trust.

⁶ See https://ec.europa.eu/growth/content/stronger-and-more-competitive-eu-industry-president-juncker-open-2019-eu-industry-days_en

⁷ Closing the loop - An EU action plan for the Circular Economy, COM(2015)614

These aims are also reflected in especially Sustainable Development Goals 3 and 10. Sustainable Development Goal 3, Good Health and Well-being for People, contains its nine health-specific targets aiming for universal health coverage for all at all ages by 2030, leaving no one behind, and ending preventable deaths. Sustainable Development Goal 10 aims, among other things, to reduce inequality within countries, ensure equal opportunity and promote social, economic and political inclusion for all.

Key targeted impacts: Investments in research and innovation within **health** (Cluster 1) will help to enable citizens to stay healthy in a rapidly changing society, including through these targeted impacts:

- Making sure we all live and work in a health-promoting environment; [by..]
- Tackling diseases and disease burden; [via ..]
- Improving access to innovative, sustainable and high-quality health care in the EU;
- Unlocking the full potential of new tools, technologies and digital solutions for a healthy society.

Investments in research and innovation concerning **culture, creativity and inclusive society** (cluster 2) will contribute to the following targeted impacts:

- Enhance democracy and good governance [through...];
- Help tackle political extremism and polarisation; [by...]
- Elucidate the societal – including political, ethical and economic - effects of technological advancements and the impact of drivers of change (such as globalisation, ageing etc.) on jobs, skills, productivity, income, welfare and inequalities;
- Build a strategy of inclusive growth and upward socio-economic convergence. Buttress the EU's resilience to economic, social, and financial shocks;
- Support the implementation of robust evidence-based strategies in the management of mobility and migration and the integration of migrants in European societies;
- Promote the value, protection, access to and sustainable use of European cultural heritage and its contribution to the cultural and creative sectors.

Sustainable Europe

Policy objectives: In order to achieve the objectives of the Sustainable Development Goals, significant changes to modernise our economy towards sustainable consumption and production patterns are needed. There is a need to reinforce efforts to fight climate change and reverse environmental degradation, promote biodiversity and the transition to a circular economy respecting planetary boundaries while maximising the potential of the Energy Union, including promoting a cleaner and more reliable energy supply to households and businesses.

These objectives also are reflected in especially Sustainable Development Goals 6 (Clean Water), 7 (Affordable and Clean Energy), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), 13 (Climate Action), 14 (Life below Water) and 15 (Life on Land).

In the areas of climate change and planetary boundaries, the EU is at the forefront in implementing the Paris Agreement. The EU has already put in place the legislation required to reach the Nationally Determined Contribution for 2030, and the Commission adopted a vision⁸ for achieving a climate neutral economy by 2050. The long-term strategy outlines a vision of the technological, economic and societal transformations required to achieve climate neutrality, and ensuring a socially fair transition that does not leave any EU citizens or regions behind. It recognises that a forward-looking research and innovation strategy should be guided by zero-carbon solutions that have the potential to be deployed by 2050, and that climate action is at the heart of Horizon Europe, with the intention of devoting 35% of the budget to climate objectives. In January 2019, the reflection paper ‘Towards a Sustainable Europe by 2030’ was adopted, with the intention to launch a forward-looking debate among citizens, Member States and other stakeholders on how to best progress on the Sustainable Development Goals.

Investments in research and innovation concerning **climate, energy and mobility** (Cluster 5) will contribute to transform the EU to a climate neutral and resilient society, especially through the following targeted impacts:

- Advance climate science and solutions
- Develop competitive cross-sectoral solutions for decarbonisation such as batteries, hydrogen, and cross-sectoral infrastructure
- Develop and apply cost-efficient, net zero-greenhouse gas energy system centred on renewables
- Develop demand side solutions to decarbonise the energy and transport systems
- Reduction of greenhouse gas emissions and increased adaptation of production systems as well as rural and urban areas to climate change; strengthening the bio-economy to supply sustainable biomaterials and bio-energy whilst staying within ecological boundaries

Investments in research and innovation concerning **food, bioeconomy, natural resources, agriculture and environment** (cluster 6) will advance knowledge, build capacities as well as develop and demonstrate innovative solutions that will accelerate the transition to a sustainable management and use of natural resources, ensuring ecosystem integrity as well as sustainable development and human well-being, including food and nutrition security, in the EU and globally. Activities under this cluster will contribute to the following targeted impacts in particular:

- Reduction of greenhouse gas emissions and successful adaptation of production systems as well as rural, coastal, peri-urban and urban areas to climate change
- Sustainable management of natural resources, prevention and removal of pollution [through..];
- Halt of decline, and restoration, of biodiversity and ecosystems services [by..];
- Sustainable management of natural resources, prevention and removal of pollution;

⁸ COM(2018) 773 final, A Clean Planet for all

- Establishment of primary production and food systems based on sustainability, inclusiveness, safety and health; securing food and nutrition security
- Better knowledge of the behavioural, socio-economic and demographic change to drive sustainability; balanced development of vibrant rural, coastal and urban areas;
- Establishment of governance models enabling sustainability.
- Support the implementation of a Built Environment fit for EU citizens and compliant with the demands on it on circularity, renovation, sustainability, energy efficiency and connectivity.

Investments in research and innovation concerning **digital, industry and space** (cluster 4) will contribute in particular to breakthroughs in low-carbon, clean and circular industries.

Influential Europe

Policy objectives: In an increasingly fractured and multipolar world, the EU will need to strengthen its position in order to guarantee its prosperity and competitive position. Through EU **international cooperation** in research and innovation, the EU can shape new technologies and solutions to global challenges, set world standards and disseminate its values.

Innovation value chains and knowledge production are increasingly global and previously emerging economies have become major players in the research and innovation area. The EU is well placed to tap into this new wealth of research excellence and resources across the world. It has a long history of international cooperation within research and innovation, lies at the centre of most international collaborative networks and offers a general openness for international participation. The EU needs to build upon and further intensify this to fully benefit from the new global opportunities. Activities should promote and integrate international cooperation based on mutual benefits, EU interests, international commitments and, where appropriate, reciprocity, with each area developing its strategy for engaging internationally, in coherence with the overall EU strategy for international cooperation in R&I.

The Sustainable Development Goals are increasingly providing a reference point to prioritise and reshape research and innovation policy agendas, and international programmatic coordination through multilateral initiatives are more and more used as a means for global cooperation in areas such as climate change, biodiversity, clean energy, sustainable cities, infectious diseases and food security. The expanding scope and interconnectivity of these challenges require that the EU strengthens its role in multilateral setups while also asserting more pro-actively EU values and interests, including in strategic alliances and networks such as global environmental conventions on climate, desertification and biodiversity, the Belmont Forum, the Group on Earth Observations, the Mission Innovation initiative, the International Bioeconomy Forum, and a range of Global Health initiatives.

Increased attention is being paid to achieve sovereignty in strategic technology areas and critical infrastructures. Though no jurisdiction is fully autonomous in terms of design, development and production of enabling technology, in a world of globe-spanning value

chains the EU should now do more to strengthen alliances with key actors in a strategic and principled way so as to ensure its competitive position.

Key targeted impacts: International cooperation in R&I is indispensable for effectively tackling global challenges and for implementing global commitments. Collaborating with the world's top researchers, innovators and knowledge-intensive companies should strengthen the EU's R&I excellence and attractiveness, increase the quality of R&I results, and reinforce the economic and industrial competitiveness of the Union. Increasing international engagement should also lead to an enhanced EU role in setting the R&I policy agendas and shaping global R&I systems and innovative solutions for the global challenges.

Engaging internationally should allow for a better assessment of challenges in their global, regional or local context, expand and diversify the flow of knowledge and increase innovation capacity, contributing also to efficient EU responses in key areas of political dialogue. The growing role of science diplomacy as an element of EU external action should foster understanding, stability and progress.

Details on the international cooperation strategy and targeted impacts for each cluster are given in the cluster specific sections.

4. Taking core values and priorities into account

The implementation of Horizon Europe will be shaped by a range of overarching European values and priorities, which will contribute to the added value of European research and innovation activities.

Gender equality is a core policy objective for all European Union activities and a crucial factor in the achievement of sustainable development and inclusive economic growth. Activities will aim at eliminating gender inequalities throughout the research and innovation systems and the gender dimension will be adequately integrated in research and innovation content across the whole programme. The latter is particularly relevant for global challenges, including in areas such as healthcare, artificial intelligence and robotics in which there is a growing worldwide recognition that gender differences, in terms of needs, behaviours and attitudes, play an important role in research design/content, and hence, determine the societal relevance and quality of research outcomes.

As described in section 2, the challenges we are facing today are of such a nature, that few can be addressed through one scientific discipline alone. **Social sciences and the humanities (SSH)** are key in understanding how human behaviour shapes not only global challenges, but also the effectiveness of the solutions we propose to meet them. For instance, SSH can contribute to our understanding of how best to engage citizens in addressing pressing concerns such as climate change and how to exploit new technologies in a way that is focused on citizens needs and concerns.

As such, SSH can contribute to strengthening the foundations of societies to embrace and drive change, whether economic, social or cultural, and thus can contribute substantially to achieving many targeted impacts across the programme. Furthermore, SSH can contribute to an increased understanding of the socio-economic impact of research policy and in the future enhance its societal impact.

The excellent and responsible research, cross-border collaboration, and ground-breaking innovation supported by Horizon Europe will, in different ways, strengthen and reinforce Europe on the global stage, across all its Member States and Associated Countries. As such, the Plan will support the aims of the Horizon Europe part **Widening participation and strengthening the European Research Area**. This includes actions to promote ethics and research integrity and continue developing a coherent framework of adherence to the highest ethics standards and the principles embedded in the European Code of Conduct for Research Integrity.

At the same time, measures supported under the part **Widening participation and spreading excellence**, that enhance research and innovation capacity in widening countries, and that spur national reforms, will over time underpin and amplify the impact of the Horizon Europe programme in itself. They aim at reducing disparities and the existing divide in research and innovation performance, but also at building up new collaborative links across the EU. They will help countries and regions that are lagging behind, including the EU outermost regions, to both contribute to HE missions and attain a competitive position in the global value chains.

The funding lines will facilitate specific research elements customised to the particular needs of the eligible less research performing countries and include actions to create new centres of excellence or upgrade existing ones (Teaming); to significantly strengthen universities or research organisations from eligible countries in a defined field, by linking it with

internationally-leading research institutions from other countries (Twinning), to support research entities organisations from eligible countries to attract and maintain high quality human resources under the direction of an outstanding researcher and research manager ('ERA Chair holder'), other measures to provide scientific networking, capacity building and career development support to young and advanced researchers from these target countries, through COST actions of high scientific quality and relevance. In addition, targeted measures will help opening up established networks for newcomers from widening countries, to improve the quality of proposals, facilitate brain circulation and launch excellence initiatives through awards and clusters. Addressing the societal, economic and technological challenges facing Europe and the world will require accelerating innovation and strengthening researchers' collaboration across borders, sectors and disciplines, using digital means to generate and openly share and disseminate knowledge in real time. It will also require a relation of trust between science and society.

Open Science practices will be mainstreamed as the new modus operandi for EU research and innovation. Particular focus will be placed on open access to scientific publications and research data, management of research data along the FAIR principles, development and consolidation of the European Open Science Cloud (EOSC) to provide a trusted and open virtual environment for data-driven research for all researchers and innovators, and responsibility and openness of science towards society, and vice versa. Open science will increase the quality of science and productivity of research and accelerate the pace and uptake of innovation to deliver on societal, economic and technological challenges. It will also give Europe a global lead in research data management. Promoting and enabling of open responsible research will help improve trust between science and society and the uptake of scientific evidence-based public policies and innovative solutions.

Activities to **disseminate and exploit results** from research and innovation will be an important and integral part of Horizon Europe, promoting public outreach. Enhanced dissemination and exploitation are strategic matters for the success of Horizon Europe and for the achievement of impact to society at large and synergies with other programmes. In addition to the initiatives concerning open science mentioned above, Horizon Europe will support actions such as clustering and packaging results/data for target audiences/networks are also envisaged, among other actions.

In many instances, new discoveries within basic research creating the foundations for excellent research and innovation impacts and leads to wide range of innovations applicable to our everyday lives. **Key Enabling Technologies** (KETs), for instance biotechnologies and advanced materials, are crucial for Europe's competitiveness in strategic value chains. Developing and mastering KETs can contribute to giving EU industries the competitive edge they need for industrial leadership on global markets; and promise breakthroughs to solve global challenges and achieve a circular, resource efficient and climate-neutral EU economy. Hence, in addition to the cluster "Digital, Industry and Space", which will help develop these technologies often as "general purpose technologies", the other clusters will also develop and apply key enabling and emerging technologies, as part of a common strategy to promote the EU's industrial and social leadership. Moreover, the Pillar I of Horizon Europe, Excellent Science, will contribute scientific breakthroughs and the research infrastructures needed to

develop key enabling technologies at their earlier phases, while Pillar III, Innovative Europe, will support breakthrough innovations based on KETs.

Research Infrastructures extend the frontiers of knowledge by providing state of the art services to research and innovation communities, thus contributing to the objectives of the clusters and missions supported in Horizon Europe. Supporting Research Infrastructures at the EU level will reduce the fragmentation of the landscape of national and regional infrastructures and strengthen the ERA as well as avoid duplication of efforts and maximise impact. As these Research Infrastructures will be connected to the European Open Science Cloud (EOSC), the involved researchers will have access to the majority of data generated and collected by Research Infrastructures as well as to HPC and exascale resources deployed under the European Data Infrastructure (EDI).

[Research and innovation are two sides of the same coin, and striking the balance between the two must be commensurate to achieving the targeted impacts described in section 3 of this document. Throughout the implementation of Horizon Europe in the different clusters of Pillar 2, this balance will be considered and adjusted to reach every targeted impact, also considering that research and innovation do not follow a simple linear model, but develop interconnectedly and rarely within rigid silos. It will also depend on regulatory, market and/or xxx conditions that ease or impede the deployment of innovative solutions and on the desired scale of such deployment. It is, moreover, taken into account that. Ultimately, the balance between research and innovation will be achieved through the implementation of the framework programme Horizon Europe as a whole, which includes the activities carried out under the other Pillars (1-Excellent Science and 3-xxx), therefore spanning, together with Pillar 2, all the range of Technology Readiness Levels from curiosity-driven research to commercially-driven innovation.]

5. New approaches and instruments for enhancing impact – Partnerships and Missions

The impact of Horizon Europe to is to a large extent dependent on the tools we use for its implementation. A special focus in Horizon Europe is that research and innovation activities are to take place in close cooperation with key stakeholders and citizens in order to enhance the impact of the activities.

Horizon Europe introduces a new approach to **partnerships** to create a simple architecture and toolbox, connecting Member States, private sector, foundations and other stakeholders in research and innovation projects; while **missions** aim to engage citizens in research and innovation by directing activities at ambitious and measurable goals.

Partnerships [Pending the inputs from the strategic coordination process, impact assessments etc.]

Horizon Europe will support European Partnerships to deliver on global challenges and industrial modernisation, through concerted research and innovation effort with the Member States, private sector, foundations and other stakeholders.

Partnerships provide mechanisms to link research and innovation closely to the policy needs of the Union, develop close synergies with national and regional programmes, bring together a broad range of innovation actors to work towards a common goal, and turn research into new solutions. As such, they are concrete attempts to address global challenges by translating broad priorities into concrete roadmaps and activities. A partnership approach is used in case it will more effectively achieve objectives and expected impacts than regular calls for proposals of Horizon Europe. Thus, European Partnerships shall be established for addressing European or global challenges only in cases where they will more effectively achieve objectives of Horizon Europe than the Union alone and when compared to other forms of support of the Framework programme. On that basis, the Commission is proposing to explore the possibility of European Partnerships for the following priorities:

[List of all partnerships⁹]

⁹ The list contains proposed co-programmed and co-funded European partnerships for possible inclusion in the strategic plan; hence, they are part of the co-design process on it. The remaining ones are the proposed institutionalised partnerships, which include initiatives according to Articles 185 and 187 TFEU and the EIT Knowledge and Innovation Communities (KICs). These do not make part of the current process and they follow their own separate paths of preparation. They are mentioned for completeness of the partnerships' landscape and as background to the choices made for the co-programmed and co-funded partnerships.

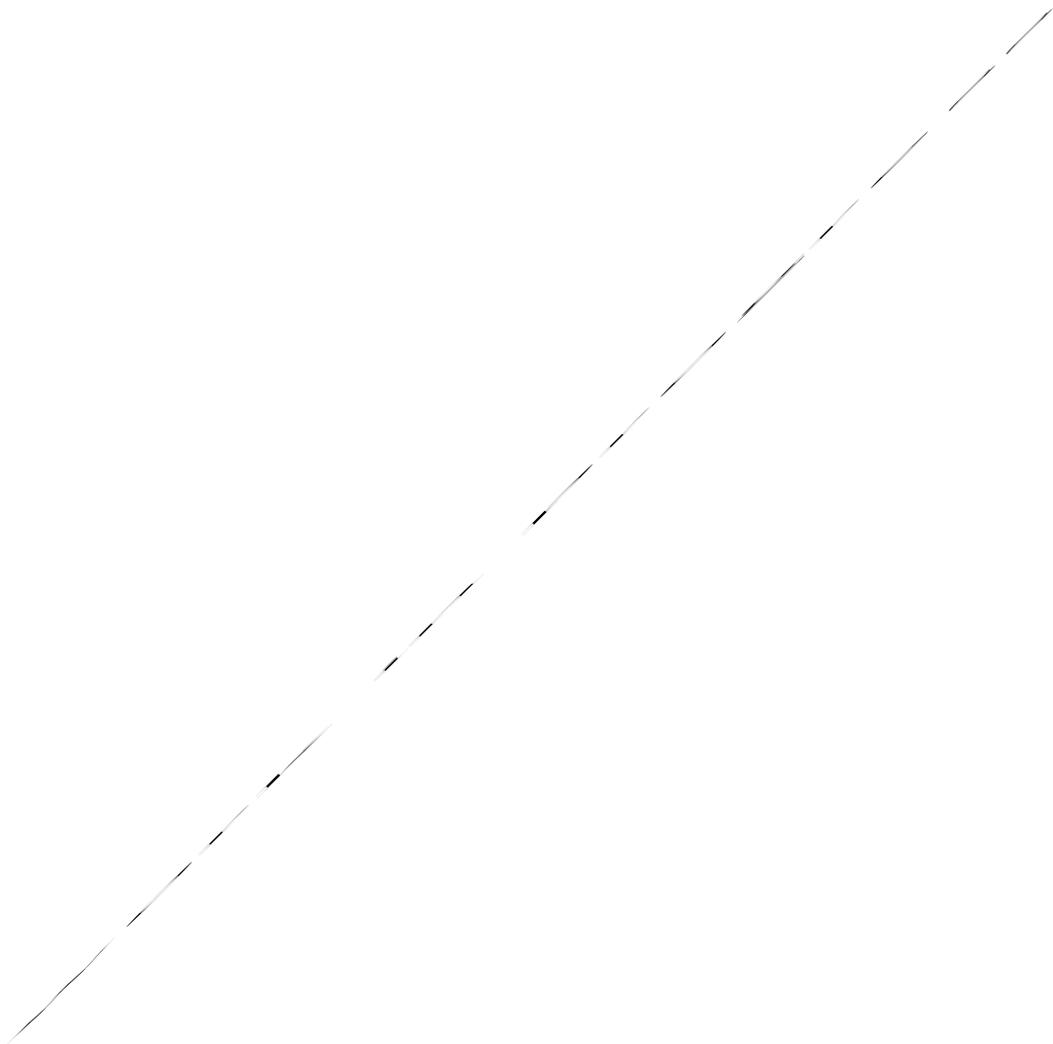
Missions [Pending the input from Mission Boards]

Missions are intended to achieve a measurable goal within a set timeframe, and impact for science and technology and/or society and citizens that could not be achieved through individual actions. They should stem from the following mission areas, which have been defined in the Horizon Europe legislative package, agreed by Council and Parliament in March and April 2019:

- Adaptation to Climate Change, including Societal Transformation
- Cancer
- Healthy Oceans, Seas, Coastal and Inland Waters
- Climate-neutral and Smart Cities
- Soil Health and Food

The Commission has taken since May 2019 first steps towards the constitution of the Missions Boards for each mission area, which will give advice to the Commission on the identification and design of one or more missions in the respective mission area. Identified missions can thus not be included in this document for co-design purposes at this stage.

KEY STRATEGIC ORIENTATIONS FOR R&I SUPPORT



HORIZON EUROPE CLUSTER 1

HEALTH

1. Global Challenges and Their Drivers

Diseases and disabilities pose a major socio-economic burden on citizens and health systems of the EU and worldwide. Non-communicable diseases, including mental illness, are responsible for up to 80% of EU health care costs. Infectious diseases, including antimicrobial resistant (AMR) infections, represent a major threat to health in the EU and worldwide. A significant part of health care costs are spent on the treatment of diseases that are, to a large extent, preventable. These global challenges call for health care systems throughout the EU that are reformed to become more accessible, sustainable, resilient and efficient in promoting and protecting everyone's health and delivering health care of good quality to all citizens. This will require new approaches for health care that integrate individual and public health management. These new approaches will have to take into account specific needs throughout the life course, the influence of the environment on human health and opportunities offered by new technologies, tools and digital solutions, and built on a competent, reliable, secure and competitive European system of health care service developers and suppliers.

R&I will be instrumental to develop these new approaches as well as to increase the knowledge and understanding that underpin innovation for health promotion, disease prevention, and treating and combatting diseases. It will also require that new, better and more cost-effective health services, technologies, tools and digital solutions become available that respond to the health needs of citizens and populations for promoting their health, preventing and combatting diseases, and assisting them in pursuing a longer, independent and active life in a rapidly changing society. Unleashing the full potential of digital technologies and health data will be a strong driver to achieve this outcome. Cooperation with other sectors will maximise societal benefits, drive innovation and ensure optimal impact. Accordingly, R&I interventions under Cluster 1 Health will be oriented towards the following six health-related challenges:

- Staying healthy in a rapidly changing society;
- Living and working in a health-promoting environment;
- Tackling diseases and reducing disease burden;
- Ensuring access to sustainable and high-quality health care in the EU;
- Unlocking the full potential of new tools, technologies and digital solutions for a healthy society;
- Maintaining a sustainable and globally competitive health-related industry.

Staying healthy in a rapidly changing society

People's health and care needs are different, depending on their age and stage of life. Their physical and mental health can be influenced by their individual situation as well as the

broader societal context they are living in. Furthermore, behaviour is an important factor. Currently, more than 790 000 deaths per year are due to risks such as smoking, drinking and obesity^{10,11}. Income, education levels and gender aspects also have an impact on health risks and how disease can be prevented. Moreover, people's health can be impacted by a rapidly changing society, making it challenging to keep pace with and navigate new technological tools and social changes, which both are increasing demands on the individual's resilience. In order to leave no one behind, to reduce health inequalities and to support healthy and active lives for all, it is crucial to provide suitable and tailor-made solutions, including for people with specific needs.

Living and working in a health-promoting environment

The environment we live and work in has direct beneficial or negative impacts on human health. It is a major determinant of health, estimated to account for almost 20% of all deaths in Europe.¹² The factors causing these impacts are not all identified nor their effects comprehensively understood and accounted for in decision-making.¹³ There are still considerable knowledge gaps in the understanding of the environmental, occupational and socio-economic risk factors for health and well-being such as pollution, chemicals, noise, radiation, urbanisation, climate change, social injustice, changing work environments, and behaviour. Also the benefits of a healthy environment need further understanding and evidence.

Tackling diseases and reducing disease burden

Communicable and non-communicable diseases cause the greatest amounts of premature death and disability in the EU and worldwide and they pose a major health and socio-economic burden to the citizens of the EU and worldwide. Many people are still dying prematurely and suffering from these diseases.¹⁴ Non-communicable diseases, including

¹⁰ Health at a glance Europe 2018 (OECD, European Commission)

¹¹ A growing health threat for children and adolescents is overweight and obesity due to raising physical inactivity combined with unhealthy eating habits. Over 60% of children who are overweight before puberty will be overweight in early adulthood. Childhood obesity potentiates the risk for developing cardiovascular disease, type 2 diabetes, physical disabilities, orthopaedic and psychological problems, and underachievement in school. Currently, in average 1 in 3 of 11-year-olds in Europe are overweight or obese and varies between countries from more than 40% in southern Europe to less than 10% in northern Europe. Obesity is one of the greatest public health challenges of the 21st century. Its prevalence has tripled in many EU countries since the 1980s. Another area of concern is the expected growth in the number of Europeans over 65 with age-related impairments from 68 million in 2005 to 84 million in 2020. It calls for new and tailor-made innovations that support the elderly in managing their impairment in daily life up to re-establishing or even enhancing human body functions and capabilities.

¹² WHO Europe: Environment and Health at <http://www.euro.who.int/en/health-topics/environment-and-health>

¹³ Annually more than 700 000 premature deaths in the EU are caused by outdoor air pollution, mostly due to chronic diseases (with heart and lung being most affected) and respiratory infections. The heat wave that swept across Europe in 2003 resulted in 70 000 premature deaths. WHO estimated that the disease burden preventable through sound management of chemicals in the environment to around 1.6 million lives per year. Between 2030 and 2050, climate change is expected to cause worldwide approximately 250 000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress. With more than 80% of the European population expected to live in urban areas by 2030, cities play a pivotal role in steering the transition towards a low-carbon society as well as in promoting and protecting health and well-being, and preventing and mitigating socioeconomic inequalities among urban dwellers.

¹⁴ Rare diseases for instance are among the major causes for death of children aged under 5 in the EU which calls for new and better tailored solutions. 75% of rare diseases manifest already during early childhood with 30 % of the patients dying before the age of 5 or leading to a dependency on care throughout the patient's life.

mental illness, are responsible for up to 80% of EU health care costs.¹⁵ These costs are spent on the treatment of diseases that are, to a large extent, preventable. Furthermore, although there is a huge potential for prevention, only around 3% of the health care budgets are currently spent on preventive measures. Moreover, digital tools hold great potential to help people stay healthy and improve the efficiency of health and care systems. Infectious diseases, including antimicrobial resistant (AMR) infections, remain a major threat to health in the EU and worldwide. AMR deaths could exceed 10 million per year worldwide according to some predictions.¹⁶

Ensuring access to innovative, sustainable and high-quality health care in the EU

Health care systems in the EU are committed to provide people with universal access to good quality health care financed on the basis of equity and solidarity. They can contribute to economic prosperity and social cohesion in the EU. It is a main priority for the EU to support Member States in ensuring that health care systems are effective, efficient, equitable, accessible, and resilient while remaining fiscally sustainable in the medium and long term. With a view to this, the role and organisation of health care systems in the EU needs to be adapted and reformed to cope with societal trends and changes that include demographic, epidemiological, technological and environmental transitions.

Unlocking the full potential of new tools, technologies and digital solutions for a healthy society

Technology is a key driver for innovation in the health sector, and can provide better and more cost-efficient solutions and can be tailored to the specific health and care needs of patients for improving their quality of life. In particular novel therapies, technologies and approaches face specific barriers and hurdles before reaching the healthcare systems, including social aspects. In addition, the availability of vast amounts of data and digitalisation offer big opportunities for transforming health and care and the well-being of millions of citizens. Succeeding in these endeavours depends on the capacity to make sense out of vast amounts of available high-quality data and of the availability of appropriate regulatory frameworks and data infrastructures that will both safeguard the rights of the individual and society, and stimulate innovation to develop efficiency enhancing and cost-effective solutions. Managing benefits and risks of all new technologies and due consideration of aspects of safety, effectiveness, appropriateness, accessibility, comparative value-added and fiscal sustainability and issues of ethical and legal nature will be crucial in order to translate these innovations into health policies, health and care systems, and clinical practice.

Maintaining an innovative, sustainable and globally competitive health industry

The health industry contributes to employment through high-value jobs and a positive trade balance, and has the capacity to provide health technologies to the benefit of patients and providers of health and care services in Europe and worldwide. The development of novel

¹⁵ Chronic diseases are the major cause for premature deaths in the EU. Currently, around 50 million people in the EU are estimated to suffer from two or more chronic conditions, and most of these people are over 65, and 22,500 people die every day in Europe from those diseases, counting of 87% of all deaths. They account for 550'000 premature deaths of people of working age with an estimated €115 billion economic loss per year (0.8% of GDP) and for up to 80% of health care costs.

¹⁶ AMR is estimated to be responsible for 25,000 deaths per year in the EU alone and 700,000 deaths per year globally. AMR also pushes up the cost of treatment and diminishes productivity due to illness: in the EU alone it is estimated that AMR costs EUR 1.5 billion annually. It has been estimated that AMR might cause more deaths than cancer by 2050.

health technologies is associated with high risks as it embraces the highest level of engineering combined with the complexity of life sciences. In addition, the health sector is strongly regulated, and many novel health technologies feature very long development times. Health industries, and in particular small and medium-sized enterprises (SMEs), may encounter difficulties to access the necessary investments, new markets and value-chains, or in setting-up partnerships and create alliances.

These health-related challenges are complex and interdependent. They have been chosen because they address a key concern and provide a clear perspective on what benefits people, patients and populations as well as institutional, social and economic stakeholders in the EU can expect from R&I interventions supported under this cluster. However, it will depend on the actors on the ground – those receiving, supporting and delivering health and care services in local communities, regions and countries – to accept, support, take-up, scale-up and implement the recommendations and innovative solutions developed through R&I to achieve the expected impacts and make universal health coverage and sustainable health security in the EU and worldwide a reality. To maximise the benefits of EU investments and support the EU in achieving its goals, the cluster health will promote and unleash synergies with other EU programmes and policies.

2. EU Policy Objectives

The *health and well-being of its people* is a central aim of the European Union, its policies and programmes. According to Article 168 of the Treaty on the Functioning of the EU, high level of human health protection shall be ensured in the definition and implementation of all Union policies and activities. With the proclamation of the European Pillar of Social Rights, the EU set the direction towards a fairer, inclusive and more social Europe for all European citizens based on a European social model that is fit for the challenges of the 21st century. Providing timely access to affordable, preventive and curative health care of good quality to everyone is amongst the key aspirations the EU and its Member States are aiming for, supported by dedicated regulations, policy strategies and programmes.¹⁷

The EU is strongly committed to the UN Sustainable Development Goals (SDGs), many of which have an important impact on health and well-being, notably SDG 3 (Good Health and Well-being for People) with its nine health-specific targets aiming for universal health coverage for all at all ages by 2030, leaving no one behind, and ending preventable deaths.

¹⁷ For instance: Directive on patients' rights in cross-border healthcare; political declaration on prevention & control of non-communicable diseases; EU decision on serious cross-border threats to health; Commission Communication on effective, accessible and resilient health systems; Commission Communication on upgrading the single market (and its proposed health technology assessments initiative); Council conclusions on nutrition and physical activity; Council conclusion on personalised medicine and pharmaceuticals; Council conclusions on strengthening the balance in the pharmaceutical systems in the EU and its Member States; EU One Health Action Plan against Antimicrobial Resistance; Ostrava Declaration on Environment and Health; Commission Communication on the digital transformation of health and care; Council recommendation on strengthened cooperation against vaccine preventable diseases; Commission Communication 'European Plastics Strategy for a Circular Economy, Commission Communication 'Towards a Comprehensive European Union Framework on Endocrine Disruptors'; Commission Communication 'European Union Strategic Approach to Pharmaceuticals in the Environment'; EU decision on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet'

EU health-related actions aim to complement national health policies and thus support EU Member States in reaching those ambitious goals, which will not be possible without a massive investment in R&I at the European and international level.

3. Expected Impacts

3.1 Staying healthy in a rapidly changing society

1. Citizens adopt healthier lifestyles and behaviours, make healthier choices and are healthier throughout the life course, including people in vulnerable stages of life or with special needs (newborn, children, pregnant women, elderly, people with physical and mental impairments, disabilities or injuries), and thus have a reduced disease burden. In particular, pregnancy and birth will become safer, and the physical and mental health and wellbeing of children (and their families) will be improved.^{18,19,20}
2. Citizens are able and empowered to manage better their own health and well-being throughout the life course as well as to maintain a healthy, independent and active life, including at old ages. They can monitor their health, adapt their lifestyle and interact with their doctors and carers (receiving and providing feedback).²¹
3. Citizens' trust in guidance from health authorities is strengthened and resulting in increased engagement in and adherence to effective health promotion and diseases prevention strategies, including increased vaccination and donation rates.²²
4. Health risks to citizens due to misinformation²³, manipulation and fraud are reduced, incl. the sale of substandard, falsified²⁴ or inappropriate medicines on the internet.
5. Health policies and policy actions for health promotion and disease prevention are better informed and tailored to specific needs of people.
6. Food systems are improved to make them more supportive for a healthy, sustainable life.
7. Maternal mortality is reduced²⁵ and preventable deaths of newborns and children under 5 years of age²⁶ are suppressed.

3.2 Living and working in a health-promoting environment

1. Citizens' health and well-being is protected and promoted, and premature deaths, diseases and inequalities related to environmental pollution and degradation are prevented.^{27,28}

¹⁸SDG 3 targets 3.3,3.4 , 3.5, 3.7, 3.8 and 3a. WHO Framework Convention on Tobacco Control, the Tobacco Products Directive 2014/40/EU, WHO Europe Health 2020 A European policy framework and strategy for the 21st century

¹⁹ EU Action Plan on Childhood Obesity 2014-2020,

²⁰ WHO Global action plan for the prevention and control of non-communicable diseases 2013-2020

²¹ Commission Communication on the digital transformation of health and care.

²² Council recommendation on strengthened cooperation against vaccine preventable diseases

²³ Commission Communication on Tackling online disinformation – a European approach

²⁴ Directive on Falsified Medicines

²⁵ SDG3 target 3.1, 3.2, 3.7

²⁶ SDG 3 target 3.2

²⁷ Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet', <http://ec.europa.eu/environment/action-programme/>.

²⁸ Ostrava Declaration of the Sixth Ministerial Conference on Environment and Health of the WHO Europe, 2017, http://www.euro.who.int/__data/assets/pdf_file/0007/341944/OstravaDeclaration_SIGNED.pdf?ua=1

2. Health burden resulting from hazardous chemicals and air, water and soil pollution and contamination is reduced, incl. at the workplace (substantially reduce the number of deaths and illnesses by 2030).²⁹
3. The EU's adaptive capacity and resilience to climate change-related health risks is strengthened.³⁰
4. European cities and regions are healthier, more inclusive, safer, resilient and sustainable.³¹
5. Policy-makers and other stakeholders are aware of environmental and occupational risk factors for health and well-being across society.³² Policies at EU and global level are thus better informed and tailored.³³
6. Citizens' understanding of complex environment and health issues and effective measures to address them is increased as well as its trust in and support for related policies and regulations.³⁴

3.3 Tackling diseases and reducing disease burden

1. Reduced health burden of diseases worldwide through effective health promotion, disease prevention and disease management, including through the development and integration of personalised medicine approaches, digital solutions and other people-centred health technologies and interventions in health and care. In particular by translating research results into new diagnostic tools and therapies, patients with a rare disease are diagnosed early and receive effective and cost-efficient treatment.
2. Premature mortality from non-communicable diseases, including rare diseases, is reduced by one third (by 2030), with an immediate impact on the related DALYs, through prevention and treatment and promotion of mental health and well-being.³⁵
3. The epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases are contained and hepatitis, water-borne diseases and other communicable diseases are being combated.³⁶
4. The nine voluntary targets of the WHO Global Action Plan for the Prevention and Control of NCDs 2013-2020 are attained by 2025, (against the 2010 baseline) with an immediate impact on the related DALYs, incl. for instance:
 - A 25% relative reduction in the overall mortality from cardiovascular diseases, cancer, diabetes, or chronic respiratory diseases;
 - Halt the rise in diabetes and obesity;
 - An 80% availability of the affordable basic technologies and essential medicines, including generics, required to treat major non-communicable diseases in both public and private facilities.

²⁹ SDG 3 target 3.9

³⁰ Ostrava Declaration of the Sixth Ministerial Conference on Environment and Health of the WHO Europe, 2017, http://www.euro.who.int/__data/assets/pdf_file/0007/341944/OstravaDeclaration_SIGNED.pdf?ua=1

³¹ Ostrava Declaration of the Sixth Ministerial Conference on Environment and Health of the WHO Europe, 2017, http://www.euro.who.int/__data/assets/pdf_file/0007/341944/OstravaDeclaration_SIGNED.pdf?ua=1

³² Ostrava Declaration of the Sixth Ministerial Conference on Environment and Health of the WHO Europe, 2017, http://www.euro.who.int/__data/assets/pdf_file/0007/341944/OstravaDeclaration_SIGNED.pdf?ua=1

³³ E.g. the EU's future 8th Environment Action Programme, follow-up to its Plastics Strategy and the Strategic Approach to Pharmaceuticals in the Environment, and the WHO environment and health process.

³⁴ Ostrava Declaration of the Sixth Ministerial Conference on Environment and Health of the WHO Europe, 2017, http://www.euro.who.int/__data/assets/pdf_file/0007/341944/OstravaDeclaration_SIGNED.pdf?ua=1

³⁵ SDG 3 target 3.4

³⁶ SDG 3 target 3.3

5. Health care systems are better prepared to respond rapidly and effectively to health emergencies and are able to prevent and manage communicable diseases transmissions, incl. within healthcare settings (hospital infections, blood safety, ...)
6. Shared health resources (interoperable data, infrastructure, expertise...) and using new technologies allowing targeted and faster research, diagnosis and treatment.³⁷
7. Reduced (cross-border) health threat of epidemics and AMR pathogens, in the EU and worldwide.^{38,39}
8. Strengthened R&I expertise, human capacities and know-how for combatting infectious and non-communicable diseases in the EU, incl. through international cooperation.
9. Continued high visibility, leadership and standing of the EU in international fora on global health and global health security, especially in partnership with Africa.
10. Enhanced patient and citizen involvement and empowerment, including health literacy, so that people are knowledgeable of the diseases threats, and thus easier adhere to knowledge based strategies and policies (especially for controlling outbreaks and emergencies).

3.4 Ensuring access to innovative, sustainable and high-quality health care in the EU

1. Health and social care services and systems have improved governance and are more effective, efficient, accessible, resilient, trusted and sustainable both fiscally and environmentally, with health promotion and disease prevention at their heart.
2. Technological innovations that meet public health needs are successfully embedded into health systems in a fiscally and environmentally sustainable way.
3. Use of innovative technologies has freed up healthcare professionals' time and resources who can better involve patients in their own care throughout the health care system
4. A shift is achieved from hospital-centred systems to community-based, people-centred and integrated health care structures.
5. Citizens play a key role in managing their health and care, informal carers are fully supported and specific needs of more vulnerable groups are recognised and addressed.
6. A societal approach is adopted to policy development, decision-making as well as evaluation of health interventions and organisations.
7. Health inequalities are reduced and universal health coverage achieved by improving access to health care services in a fiscally sustainable manner, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all.⁴⁰

3.5 Unlocking the full potential of new tools, technologies and digital solutions for a healthy society

1. Increased scientific and technological expertise and know-how providing Europe with the capacity for innovation in health technologies and data on a global level.
2. Better informed policies and tailored legal and ethical frameworks supporting the development of innovative health technologies.
3. Increased knowledge on the impact of digitalization on the society

³⁷ Commission Communication on the digital transformation of health and care.

³⁸ WHO global action plan on antimicrobial resistance, 2015.

³⁹ EU One Health Action Plan against AMR, 2017.

⁴⁰ [SDG 3 target 3.8](#)

4. Citizens are involved, informed and support the opportunities offered by new technologies for health and care, while endorsing the way potential risks are managed.
5. Health care providers monitor and analyse activities, are aware, trained and apply new technologies.
6. Europe's capabilities and potential for health technology innovation is world-class, while use of health data is safe and secure.
7. Targeted, safer and faster research, diagnosis, and treatment, and improved disease prevention and monitoring for better patient outcome and well-being, including through shared health resources (data, infrastructure, expertise).
8. Safer, more efficient and cost-effective health care tools, technologies and solutions.

3.6 Maintaining an innovative, sustainable and globally competitive health industry

1. Health industry in the EU is more competitive, sustainable and growing, providing high-value jobs and contributing to economic growth, in particular SMEs. It taps into new markets and provides European leadership in breakthrough health technologies and innovations.
2. SMEs gain the ability to grow and reach a critical mass to develop innovative products and services in Europe and to tap into international value chains and access international markets.
3. Time-to-market for innovative health technologies and services (e.g. medicines, vaccines, diagnostics, medical devices, secure digital and data-driven solutions) is decreased, enabling a swift uptake into health care systems for the benefit of citizens and health care providers.
4. European health industry is working more efficiently along the value chain from the identification of needs to the scale-up and take-up of solutions at national, regional or local level, including through early engagement with patients and health care providers.

Reliable access to key manufacturing capacity that supports the security of the EU, including timely provision of essential medical supplies of particularly complex supply and distribution chain.

4. Key R&I Orientations

The present section focuses on what R&I interventions and results are needed to tackle the health-related challenges and contribute to achieving the desired impacts.

4.1 Staying healthy in a rapidly changing society

R&I can provide a better understanding of specific health and care needs throughout the life course, including its impact on aging, and develop more effective solutions for health promotion and disease prevention. This includes preventive health measures through cultural and artistic means, personalised solutions for individuals as well as stratified solutions tailored to groups living with chronic health conditions, physical and mental impairments or disabilities. Actions will target in particular people in vulnerable stages of life and people living in socioeconomic situations with structural disadvantages. R&I can help people, as well as communities, in developing innovative services, policies and digital solutions, also ensuring that they are accessible, equitable and effective in preventing disease and promoting health. Key to achieving these objectives is the availability and accessibility of real-world health data, which will require appropriate support by research and data infrastructures.

This R&I orientation will support activities aiming at:

1. Better understanding of human health at various developmental stages and their impact on ageing, including individual factors affecting health and individual resilience to diseases.
2. Better understanding of specific health needs, including those of people in vulnerable stages of life, people with physical/mental impairments, population groups in socioeconomic situations with structural disadvantages, and better solutions addressing those needs.
3. Personalised solutions for health promotion and disease prevention of individuals or stratified solutions tailored to groups, incl. for improved prediction and prevention of diseases before/at birth.
4. The development of digital tools and applications fostering health literacy and empowering citizens to better manage their own health and well-being throughout their life course, incl. for countering health-related misinformation, manipulation and fraudulent internet sales of substandard, falsified or inappropriate medicines and illicit drugs.

Areas of Intervention: This challenge requires R&I actions under several Areas of Intervention (AoI) of cluster 1 but the centre of gravity lies with AoI 1.2.1. ‘Health throughout the Life Course’. It is closely linked to AoI 1.2.2 ‘Environmental and Social Health Determinants’ as well as to cluster 2 “Inclusive society”, cluster 5 “Climate, energy and mobility” and cluster 6 “Food and natural resources”.

Cross-cluster issues: Synergies with other clusters could be explored through broad cross-sectoral collaboration. For example with cluster 2 ‘Inclusive societies’ on health inequalities or cluster 6 ‘Food and natural resources’ on the rôle of nutrition for health (incl. human microbiome, mal- and over-nutrition, safe food), personalised diets (incl. food habits in general and childhood obesity in particular) and the impact of food-related environmental stressors on human health (incl. marketing). Other possible synergies could be explored by cooperating on digital tools, telemedicine or smart homes with cluster 4 ‘Digital and Industry’ or with cluster 5 ‘Climate, Energy and Mobility’ on urban health or on mitigating the impact of road traffic accidents and related injuries.

International cooperation: Similar health challenges and needs for health promotion and disease prevention are faced by other regions and countries. International cooperation should be sought and promoted in order to benefit from new knowledge and solutions as widely as possible.

4.2 Living and working in a health-promoting environment

R&I will produce the knowledge necessary to identify and assess the risks and benefits for health, and to enable health promoting and disease preventive policy actions. Results will support the EU’s environment and health policies and overarching policy frameworks such as the future 8th Environment Action Programme, the EU Strategic Framework on Health and Safety at Work⁴¹ and the European Environment and Health Process (EHP)⁴². The outcome will also contribute to the development of new and improved health interventions and technologies. In order to achieve sustainable impacts, R&I must provide solid evidence and stimulate its uptake into a large number of environmental, occupational, social and health

⁴¹ <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0332>

⁴² http://www.euro.who.int/__data/assets/pdf_file/0009/341946/Annex2_20June.pdf?ua=1

policies at the EU, national and regional level. Strong collaborations across sectors and with other Horizon Europe clusters dealing with issues such as agriculture, food, environment, climate, mobility or urban planning will be needed to ensure that maximal societal benefits will be reached. Likewise, international cooperation, including at science-policy level, will be key to drive forward and tackle this challenge.

This R&I orientation will support activities aiming at:

1. Collection, combination and analysis of environmental, occupational and human health-related data, taking advantage of the exposome approach.
2. Identification and characterisations of emerging and persistent environmental, occupational and climate change-related stressors.
3. Establishment and quantification of causal relationships between exposure to the identified stressors and health impacts.
4. Development of innovative methods to better estimate the economic and health costs of exposure to identified stressors and co-benefits of preventive actions across sectors.
5. Translation of research results into early warnings and evidence for regulatory preparedness, targeted at policy levels where action is needed.
6. Elaboration of cross-sectoral approaches to mitigate and prevent adverse health outcomes and promote beneficial health impacts, together with actors inside and outside the health area.

Areas of Intervention: This challenge involves R&I actions under several Areas of Intervention (AoI) of cluster 1 and other clusters, but the centre of gravity lies with AoI 1.2.2. 'Environmental and Social Health Determinants'. It is closely linked to AoI 1.2.1 'Health throughout the Life Course' as well as to cluster 3 "Secure society", cluster 5 "Climate, energy and mobility" and cluster 6 "Food and natural resources".

Cross-cluster issues: Synergies with other clusters could be explored through broad cross-sectoral collaboration, for example with cluster 6 'Food and natural resources' on human biomonitoring, on healthy ecosystems and human habitats (incl. nature-based solutions health and well-being), or on the sustainable management of clean water, soil and air. Other possible synergies could be explored by cooperating with cluster 4 'Digital, Industry and Space' on health-related space R&I for location-based services, geo-observation and monitoring (e.g. of pollution), with cluster 5 'Climate, Energy and Mobility' on the surveillance, prediction and mitigation of the health impact of climate change or on concepts/technologies for smart and healthy homes, rural areas and cities, and with both cluster 4 and 5 on health impact assessment, e.g. the impacts on health and well-being of infrastructure, urban planning, transport or technologies.

International cooperation: Exposures to environmental stressors of relevance to human health are not confined locally but transcend national borders and are connected to global political and economic relationships and interactions. International cooperation is thus key to tackle this challenge effectively, including by cooperating with international actors and initiatives like the WHO and the WHO Europe environment and health process (incl. WHO European Centre for Environment and Health, Chemical Risk Assessment Network, Global EMF project); United Nations Environment Programme; US National Institute for Environmental Health Sciences; US CDC (NHANES biomonitoring programme); US Environmental Protection Agency; OECD (chemicals testing).

4.3 Tackling diseases and disease burden

There is an urgent need for R&I on new therapies, vaccines, diagnostics, and alternatives to antibiotics, as well as to improve existing prevention strategies to create tangible impacts. To address these challenges of global dimension, it will require international cooperation to pool the best expertise and know-how available worldwide, to access world-class research infrastructures and to leverage critical scales of investments on priority needs through better alignment with other funders of international health R&I cooperation. The continuation of international partnerships and cooperation with international organisations is particularly needed to combat infectious disease and respond to major unmet needs for global health security.

This R&I orientation will support activities aiming at:

1. Better understanding of diseases and their drivers, incl. the causative links between environmental factors and diseases, and better evidence-base for policy-making.
2. Better methodologies and diagnostics that allow timely and accurate diagnosis, identification of personalised treatment options and assessment of health outcomes, including for patients with a rare disease.
3. Development and validation of effective intervention for better surveillance, prevention, treatment and crisis management of infectious disease threats.
4. Novel and improved innovations and health technologies developed and tested in clinical practice, including personalised medicine approaches and using digital tools to optimise clinical workflows.
5. New therapies for non-communicable diseases, including rare diseases developed in particular for those without approved options, supported by strategies to make them affordable for the public payer.
6. Scientific evidence for improved informed/tailored policies and legal frameworks and to inform major policy initiatives at global level (e.g. WHO Framework Convention on Tobacco Control; UNEA Pollution Implementation Plan).

Areas of Intervention: This challenge requires R&I actions under several Areas of Intervention (AoI) in cluster 1 but the centre of gravity lies with AoIs 1.2.3. ‘Non-Communicable and Rare Diseases’ and 1.2.4. ‘Infectious Diseases’. It is closely linked to AoI 1.2.2 ‘Environmental and Social Health Determinants’ as well as to cluster 3 “Secure Society” and cluster 6 “Food and natural resources”.

Cross-cluster issues: Synergies with other clusters could be explored through broad cross-sectoral collaboration, for example with cluster 3 “Secure Society” on health security/emergencies (preparedness and response, medical counter measures, epidemic outbreaks/pandemics, natural disasters and technological incidents, bioterrorism), or with cluster 4 “Digital, Industry and Space” on decision-support systems or on geo-observation and monitoring (e.g. of disease vectors, epidemics). Other possible synergies could be explored by cooperating with cluster 6 “Food and natural resources” on health security and AMR (one-health: human/animal/plant health). Specific synergies with other clusters will be agreed once an advanced draft of the strategic orientation of other clusters is available.

International cooperation:

4.4 Ensuring access to innovative, sustainable and high-quality health care in the EU

R&I can help by supporting the development of innovative solutions for health care systems in all their various dimensions (e.g. governance, financing, generation of human and physical resources, health service provision, patient empowerment). In addition, R&I can provide decision-makers with evidence, methods and tools to successfully implement those innovative solutions into their health care systems. It will in turn help to improve the governance of health care systems as well as to allocate resources according to people's needs and preferences while delivering fiscal sustainability to make sure those needs can be met in the long-term.

This R&I orientation will support activities aiming at:

1. Innovative solutions to inform reforms in health care systems (e.g. organisational models, incl. innovative health service delivery models, integrated care models, long-term care; digitalised services, personalised approaches financing models, incl. financing of health care systems, remuneration models, incentive mechanisms, new payments/reimbursement models of health technologies⁴³; human resources planning, education and training, incl. as regards the effects of the environment on health and the environmental sustainability of health care).
2. Methods, tools and demonstrated pilots for uptake and scale-up of innovation in health systems (e.g. technological innovation, organisational innovation), as well as for their transferability/adaptation from one country/region to another.
3. Simulation models to support policy-making, taking into account the complexity and specificities of health systems and the need to protect access and pursue long-term fiscal sustainability.
4. Innovative solutions to support people-centred health and care throughout the life course: innovative solutions improving citizen empowerment, access of citizens to their own health data, health literacy, self-care, informal care, and community care..
5. Framework for better interoperability between data sources and infrastructures, for sharing, access, use and analysis of real-world data that will in turn improve the efficiency of health systems by strengthening their governance, informing policy development and decision-making, facilitating monitoring and evaluation of health interventions with due attention to security, data protection, privacy, interoperability, standards, comparability and integrity.
6. Innovative full health technology assessment methods (i.e. including all relevant aspects such as clinical effectiveness, cost-effectiveness, ethics, organisational aspects, etc.) to support better allocation of resources: disinvestment from obsolete/inefficient health interventions and investment in innovations that bring added value for patients such as personalised medicine, digitalised services, personalised treatment pathways, people-centred models of care, programmes for disease prevention and health promotion, as well as public health policies.
7. Methods to assess performance and efficiency of healthcare organisations and health systems based on outcomes that matter for patients and carers (formal and informal), aiming at reducing health inequality and allowing for international comparability.

⁴³ WHO definition of 'health technology': A health technology is the application of organized knowledge and skills in the form of devices, medicines, vaccines, procedures and systems developed to solve a health problem and improve quality of lives.

8. Identification of factors accounting for health systems resilience in absorbing the impact of crises and accommodating disruptive innovation.

Areas of Intervention: All R&I areas of cluster 1 are concerned but the centre of gravity lies with AoI 1.2.6 ‘Health Care Systems’. It is closely linked to AoI 1.2.1 ‘Health throughout the Life Course’ as well as AoI 1.2.5. ‘Tools, Technologies and Digital Solutions for Health and Care’.

Cross-cluster issues: Synergies with other clusters could be explored through broad cross-sectoral collaboration, for example with cluster 3 “Secure Society” on health economics and economic models, on cost-effectiveness, fiscal sustainability and accessibility of healthcare, or on adaptation of public health systems to societal challenges (climate change, migration, demographic change) thereby contributing to building resilience. Other possible synergies could be explored by cooperating with cluster 4 “Digital, Industry and Space” on cybersecurity of (public) health systems, products and infrastructures of digitalised health and care, or on health impact assessment (e.g. related to consumer products, working place innovation).

International cooperation: Cross-border learning from practices and good models of care is key in this area of research. Research will benefit from cooperation with international actors: such as World Health Organization and public health institutes (e.g. Canadian institutes of health research and Agency for healthcare research and quality (AHRQ) in the United States that are already partners of EU-funded projects in health systems research).

4.5 Unlocking the full potential of new tools, technologies and digital solutions for a healthy society

R&I is needed on the large spectrum of tools and technologies for bio-medical research, prevention, diagnosis, therapy and monitoring. Managing benefits and risks of new technologies and due consideration of aspects of safety, effectiveness, appropriateness, accessibility, comparative value-added and fiscal sustainability and issues of ethical, social and legal nature will be crucial in order to translate these innovations into health policies, health and care systems, and clinical practice. Moreover, R&I could address specific unmet needs for health tools, technologies and digital solutions with limited commercial interest. Artificial Intelligence technologies have recently shown great promise for analysing high volumes of health data, with high potential for advancing biomedical research, personalised medicine and innovative solutions in health and care.

This R&I orientation will support activities aiming at:

1. New tools and technologies for bio-medical research, prevention, diagnosis and therapy of diseases and tools for monitoring diseases as well as treatment progression, including digital solutions, Artificial Intelligence applications, genomics and other data-driven interventions and procedures, are designed, developed, tested or validated for the benefit of patients and the health and care systems.
2. Health data accessibility and interoperability across the EU, including the free flow of data and the creation of a European health cloud(s) for research purposes and exchange of data.
3. Novel methodologies and metrics adapted to new tools, technologies, digital solutions and interventions for their assessment, validation and translation into health care practice,

including ethical aspects, their societal effects and integration into regulatory frameworks, and for allowing swift access by providers of health care, patients and healthy citizens.

4. Improved risk-benefit ratio of the developed innovative tools, technologies owing to powerful digital solutions using and processing all kinds of data, including real-world data, for efficient value assessment.
5. Efficient up-scaling and production systems, including advanced manufacturing techniques, enabling targeted and personalized health interventions.
6. Improved health technologies and interventions based on digital solutions, which support timely health information and use of health data.
7. New data-driven approaches, computer models and -simulations and other digital solutions, including smart data infrastructures and AI-based data analytics, are developed, translated and optimised for health care and person-centred care.

Areas of Intervention: This challenge will benefit from R&I actions under several Areas of Intervention (AoI) of cluster 1 but the centre of gravity lies with AoI 1.2.5 ‘Tools, Technologies and Digital Solutions for Health and Care’. It may be inspired by R&I actions supported under pillar 1 (Open Science), is closely linked to R&I actions on key emerging technologies of cluster 3 “Digital and industry” and may trigger follow-on support under pillar 3 (Open Innovation).

Cross-cluster issues: Synergies with other clusters could be explored through broad cross-sectoral collaboration, in particular with cluster 4 “Digital, Industry and Space” on: digitalisation of the health sector, incl. health technologies⁴⁴ and medical devices; assisted, autonomous, independent and empowered living; smart homes; decision support systems; health impact assessment (e.g. related to consumer products, working place innovation).

4.6 Maintaining an innovative, sustainable and globally competitive health industry

There is a need for R&I to strengthen the single market, including by implementing the Digital Single Market strategy, supporting the standardisation policy, driving innovation from the demand side and providing evidence and guidelines for stakeholders and regulators to ensure take-up of innovations supports fiscal sustainability while protecting access.

This R&I orientation will support activities aiming at:

1. Efficient innovation management strategies, including intellectual property, to translate breakthrough technologies into health care applications.
2. Efficient collaboration with regulatory authorities for an optimal time to patient access.
3. Regulatory authorities are supported with better methodologies and interdisciplinary approaches to assess new health technologies and interventions.
4. New European standards and quality assurance schemes are submitted to standardisation bodies and implemented by stakeholders
5. Safe and clinically validated tools, technologies and services are developed and delivered by the European health industry that meet the needs of health care providers and systems.
6. The development of greener pharmaceuticals is supported.

Areas of Intervention: All R&I areas of cluster 1 are concerned but the centre of gravity lies with AoI 1.2.5. ‘Tools, Technologies and Digital Solutions for Health and Care’, while it is closely linked to AoI 1.2.6 ‘Health Care Systems’. There are links to cluster 4 “Digital, Industry and Space” and pillar 3 “Open Innovation”, in particular the scheme of the European Innovation Council that supports breakthrough and risky innovations.

Cross-cluster issues: Synergies with other clusters could be explored through broad cross-sectoral collaboration, in particular with cluster 4 “Digital, Industry and Space” on: industrial R&I infrastructures (pilot plants, testing and simulation facilities, open innovation hubs); additive manufacturing (3D/4D printing) and other production technologies (incl. biomanufacturing); safe, smart and sustainable materials. Potential synergies will be identified once an advanced draft of the strategic orientation of cluster 4 is available.

European Partnerships

HORIZON EUROPE CLUSTER 2

CULTURE, CREATIVITY AND INCLUSIVE SOCIETY

1. Global Challenges and Their Drivers

The EU stands for a unique way of combining economic growth with high levels of social protection and inclusion, shared values including democracy, human rights, and the richness of diversity. This model is constantly evolving and needs to deal with the challenges from amongst other things, demographic change, globalisation and technological change.

Activities in Cluster Culture, Creativity and Inclusive Society focus on challenges pertaining to democratic governance, cultural heritage and creative economy, social and economic transformations. The challenges are interconnected and have been chosen because they respond to the most pressing social, political, economic and cultural concerns and expectations of European citizens. They provide a clear picture of what benefits citizens and different stakeholders can expect from R&I actions supported under this cluster. The key R&I priorities will respond to the following challenges:

1) Enhancing democratic governance

Democracies are more fragile and more vulnerable than in the past. The Freedom in the World Report (2018) shows that democracy across the globe faces its most serious crisis in decades. At the same time, various European surveys show declining levels of trust to the political institutions of democracy. In terms of legitimacy, there are signs of a potential shift from governance based on expertise, multilateralism, and consensual policymaking towards majoritarianism, unilateralism, nationalism, and polarization. Relevant research can support policy action in favour of democracy, its stability, and its further development with a view to enhancing representation, participation, openness, pluralism, tolerance, cultural participation, respect of diversity including cultural expressions, non-discrimination, the protection of fundamental rights and the rule of law⁴⁵.

2) Promoting Cultural Heritage

Cultural heritage is the expression of the ways of living a society has developed by common values, traditions and beliefs and the different influences it has been exposed to and absorbed over time. It gives a sense of belonging to people and anchors our societies into their past while allowing them to project themselves into the future. Opinion surveys show that cultural heritage is important for the overwhelming majority of European citizens, who also believe that public authorities should allocate more resources to its protection⁴⁶. The EU's "United in

⁴⁵ Merkel W. (2019 forthcoming) Past, present and future of Democracy: A Policy Review of Framework Programme Projects. DG RTD/EC.

⁴⁶ Special Eurobarometer 466 (2017) on cultural heritage;
Sonkoly, G. and Vahtikari, T. (2018) Innovation in Cultural Heritage Research: For an Integrated European Research Policy. DG RTD/EC.

Diversity” motto finds a tangible expression in cultural heritage. Historical sites and monuments, cultural landscapes, artefacts, museums, archives, as well as languages, customs, traditions, behaviours, beliefs and values all make up the rich tapestry of European cultural heritage. This makes Europe a vibrant and unique place to tackle future challenges based on its creativity, excellent research, sustainable cultural tourism and cutting-edge technologies.

Cultural Heritage needs to make the best use of the opportunities brought by the digital transformation. It needs to combine traditional craftsmanship, cutting edge and digital technologies for the preservation and restoration of cultural goods with innovative techniques in the cultural and creative industries with a view to the creation of jobs, growth and wealth.

3) Management of social and economic transformations

Together with other challenges like climate change, the transition to a low carbon economy and demographic developments, technological advancements pose multidimensional social (economic, ethical, cultural and political) challenges. In the realm of work, productivity and welfare, as well as in the way we live and learn, the impact of automation could be substantial. A full deployment of existing new technologies in the production process could lead to automation rates of one third to two thirds of today's tasks.⁴⁷ According to other estimates, approximately 14% of jobs in the OECD countries are highly automatable, equivalent to 66 million jobs.⁴⁸ At the same time, there has been an increase in income inequality and labour market polarisation, and a slowdown in convergence in income and employment in most European countries⁴⁹. Inequalities threaten social and territorial cohesion and economic growth. They also create obstacles in participation in political life and can thus undermine the stability of democracies. Against this background, the creative economy has become a powerful transformative force in the world economy. It could drive to a more inclusive society and economy⁵⁰.

In recent years, Europe experienced the arrival of an increased number of migrants, including asylum seekers. Migration has become a crucial issue for Europe, one that is likely to dominate policy and political agendas for many years to come. Migration is a challenge requiring comprehensive and coordinated European responses, both inside and outside the EU, involving Member States, EU actors, as well as local and regional authorities, civil society organisations and economic and social partners. The task of research is to better understand migration in a global and EU context and assist in its governance and enhance

⁴⁷ See in particular European Commission (2018), Employment and Social Developments in Europe (ESDE) Annual Review, “The new world of work: Beyond digitalisation”, July 2018, https://ec.europa.eu/commission/news/employment-and-social-developments-europe-2018-jul-13_en

⁴⁸ Nedelkoska, L. and G. Quintini (2018), “Automation, skills use and training”, OECD Social, Employment and Migration Working Papers, No. 202, OECD Publishing, Paris.

⁴⁹ Eurofound (2017), Income inequalities and employment patterns in Europe before and after the Great Recession, Publications Office of the European Union, Luxembourg.

Kvist, J. (2016) Fighting Poverty and Exclusion through Social Investment – A European Research Perspective. DG RTD/EC;

Allmendinger, J. (2015) An ever closer union among the peoples of Europe? - Rising inequalities in the EU and their social, economic and political impacts. DG RTD/EC.

⁵⁰ Creative Economy Report (2013) United Nations/UNDP/UNESCO

integration. It can enhance policies by providing evidence on the causes and consequences of the phenomena and facilitate timely response by identifying trends and suggesting possible policy solutions. Research should contribute to integration, through dispelling myths and biases⁵¹.

2. EU Policy Objectives

Cluster 2 Culture, Creativity and Inclusive Society aims to foster greater understanding of a culturally and socially rich and diverse Europe and show how it can benefit most from adopting new paradigms, and policies for change in a context of fast paced transformations and international interconnectedness. Although the challenges are great, so too are the opportunities to turn these into strengths through European cohesion, convergence, diversity and creativity across all areas of the economy, society, culture and governance.

Thus, there is a need for research and innovation that increases our knowledge about the current developments of European societies and that directly develops solutions for the future. To promote new thinking and provide solutions to social and economic challenges, the full integration of cultural and creative sectors into research and innovation processes is essential. Approaches should be inter-disciplinary, inclusive, cross-sectorial, cross-national, and comparative allowing the identification of change factors while elaborating innovative theories, applications and policy recommendations for moving forward. In doing so, they should also make best use of the ongoing big data revolution in the social sciences and the humanities.

Cluster 2 will address EU priorities on Democratic Change; Jobs Transformation, Growth and Investment; Migration; Justice and Fundamental Rights; A Deeper and Fairer Internal Market; Making the EU a Stronger Global Actor; Cultural Heritage.

3. Expected Impacts

Delivering on Horizon Europe's impact pathways Cluster 2 Culture, Creativity and Inclusive Society strategic R&I activities will:

- Support policy action in favour of democracy, its stability, and its further development with a view to enhancing representation, participation, openness, pluralism, tolerance, cultural participation, respect of diversity including cultural expressions, non-discrimination, the protection of fundamental rights and the rule of law.
- Help tackle political extremism and polarisation.
- Help protect historical sites and monuments, cultural landscapes, artefacts, museums, archives, as well as languages, customs, traditions, behaviours, beliefs and values all make up the rich tapestry of European cultural heritage
- Support EU migration and mobility policies, both internal and external.
- Help reverse social, economic and political inequalities.
- Contribute to a comprehensive European strategy for inclusive growth and upward convergence in employment and social affairs.

⁵¹ King, R. and Lulle, A. (2016) Research on Migration: Facing Realities and Maximising Opportunities. DG RTD;

- Assess and respond to the social, ethical, political and economic impacts of technology in the wide variety of social, economic and territorial contexts in Europe.
- Create high quality new knowledge and foster its diffusion.

4. Key R&I Orientations

R&I activities in this Cluster will help develop new statistical tools and methodologies for economic and social analysis and foresight in all (three) Key R&I Orientations outlined below; render this knowledge base more easily accessible, comparable at EU level, and improve the granularity of its findings, with due focus on distributional and territorial impacts.

In this context this priority will:

- Build up evidence and policy recommendations on enhancing democracy and good governance;
- Elucidate the societal – including political, ethical, cultural and economic - effects of technological advancements and the impact of drivers of change (such as globalisation, ageing etc.) on jobs, skills, education, productivity, income, welfare and inequalities.
- Develop evidence-based policy recommendations on how economic sectors, including the cultural and creative sectors and the social economy, can address social and economic transformations.
- Help develop evidence based policy responses for inclusive growth and upward socio-economic convergence. Buttress the EU's resilience to economic, social, and financial shocks.
- Develop and test innovative approaches that address social challenges, including via experimentation, behavioural studies and social innovations.
- Contribute to the implementation of internationally agreed agendas (SDGs, decent work agenda, etc.) and the promotion of EU core values;
- Support the implementation of robust evidence-based strategies in the management of mobility and migration and the integration of migrants in European societies.
- Promote the value, monitoring, protection, access to and sustainable use of European cultural heritage and its contribution to the cultural and creative sectors.

Build evidence of the innovation capacity of cultural and creative industries and their role as innovation triggers in other economic sectors.

4.1. Democracy and Governance

The implementation of these research activities will assist in the re-invigoration and modernisation of democratic governance. The aim is to develop innovations, policies and institutions that expand political participation, social dialogue and civic engagement, gender equality, enhance transparency, accountability and legitimacy, improve trust in democratic institutions, safeguard pluralism, liberties and the rule of law, and protect democracy from multidimensional threats. In the medium to long term, the knowledge, data, scientifically robust recommendations and innovations generated will enhance decision making on all aspects relevant to democratic governance:

- R&I will support and strengthen core democratic values. While enshrined in international, EU and national laws, pluralism, tolerance, non-discrimination, justice, solidarity, human dignity, are all concepts that require a deeper analysis of the meaning they have in our societies. This includes the analysis of the practices through which such meanings emerge and are sustained.
- Research will also serve to foster awareness and exercise of democratic rights and enhance active citizenship (including from the perspective of vulnerable and under-represented groups)⁵². It will help restore trust in governance, close the gap between perceptions and reality, and respond to threats to the electoral process and democracy⁵³. Activities will empower citizens to manage better their personal data, including data created and/or accessed by public administrations.
- Knowledge generated should allow the formulation of policy recommendations in support of transparency, responsiveness, accountability, inclusiveness and effectiveness of democratic governance at all levels.
- Similarly, activities in the Cluster will feed into EU policies on the protection of fundamental rights and the application of the rule of law.
- R&I will help address the impacts and explore the potential as well as the challenges of technological and scientific advancements, including big data, geo-information systems, online social networks and artificial intelligence on democracy. It will also aim to increase transparency and accountability of governments and lead to the development of strategies to counterbalance disinformation and the manipulated polarisation of public opinion.
- As such, it will also help assess the state of safeguards of democratic systems, analysing in this context the role of media, including digital media. Research will also help understand social network communication and build on education and media literacy as gateways to democratic participation. Knowledge generated will lead to recommendations regarding the role of digital technology in participatory democracy and active and inclusive citizenship.
- R&I will also target culture's value to democracy, by analysing relationships between a number of culture and democracy dimensions such as active cultural engagement and democratic openness; political engagement; trust in society and well-being.
- Finally, activities funded under this R&I priority will systematically analyse the impact of economic and socio-spatial inequalities on political representation and participation and explore ways to reverse negative trends.

4.2 Cultural Heritage

The implementation of these research activities will result in better access, understanding of and engagement with cultural heritage. They will support the emergence of a sense of belonging based on the common roots and riches of the diversity of European cultural heritage. R&I results will contribute to European integration by providing better, wider and

⁵² Ensure the equal enjoyment of all human rights and fundamental freedoms for persons with disabilities as per the UN Convention on the rights of persons with disabilities.

⁵³ Kepel, G. and Rougier, B. (2016) Addressing terrorism: European Research in Social Sciences and the Humanities in Support to Policies for Inclusion and Security. DG RTD/EC;

more equal access to culture, cultural heritage and the arts. Knowledge generated will support the emergence of new forms of cultural expression, at the cross roads between different creative sectors. Horizon Europe activities will also enhance the governance of European cultural heritage institutions and networks. Most importantly, they will improve protection, enhancement, conservation and more efficient restoration of European cultural heritage. Research activities shall increase the quality standards for conservation and restoration of European cultural heritage. R&I will provide solutions for making the EU a world leader in cultural heritage conservation technologies, management, digitisation and curation of digital heritage assets. Supported activities will provide research and innovation for developing sustainable and inclusive cultural tourism in Europe. They will also increase capacities for the protection of endangered cultural heritage and deployment of preventive measures against the illicit trade in cultural goods. R&I will support Cluster activities will support policies leading to greater gender equality in the cultural heritage sector. They will also help the preservation of endangered languages. Finally, R&I will support sustainable growth and job creation through contributing to a European industrial policy for cultural and creative industries including design.

- Support the EU's policy objective in monitoring, preserving and transmitting cultural heritage, fostering cultural and creative sectors and promoting cultural diversity.
- Share and boost access to and participation in cultural heritage through innovative approaches, new and emerging technologies, including digitisation and increased cultural literacy. Support the use of digitised historical collections and archives for ground-breaking new interpretations of the past.
- Build on the role of intangible heritage, traditions, behavioural patterns, perceptions, beliefs, values and identities and new forms of cultural expression in the development of new approaches for more cohesive, and sustainable societies.
- Promote new educational and training paths and skills to make the existing cultural heritage protection practices compatible with societal transformation (data society).
- Promote policies and projects leading to ensuring gender equality in the cultural heritage sector.
- Develop cutting-edge conservation and restoration technologies and methods and provide innovative, integrated, sustainable and participative management models.
- Connect cultural heritage with the creative and cultural sectors, with a view to spurring inclusive growth, jobs, social cohesion and diversity.
- Break the boundaries between creativity, production, promotion and access to content, innovative business models and technological advances in the cultural and creative sectors and link analogue and digital heritage and intercultural cooperation.
- Research old and new forms of cultural and artistic expression to promote tangible and intangible heritage and intercultural cooperation and valorise traditional skills and reuse existing assets.
- Provide research capacities for European cultural diplomacy and for underpinning the European Union's leading role in international cooperation for preventing and fighting illicit trafficking in cultural goods and for the protection of endangered cultural heritage, also in conflict zones.
- Develop new approaches, concepts and practices for sustainable, accessible and

inclusive tourism, including cultural tourism.

- R&I will contribute to sustainable development through research and innovation for the conservation, safeguarding, developing and regeneration of cultural landscapes.

4.3 Social and Economic Transformations

The implementation of these research activities will contribute to a comprehensive European strategy for inclusive growth, ensuring no one is left behind, including through the accumulation and preservation of human capital in the face of old and new risks. It will equally support productivity gains and social and economic resilience. The knowledge generated will feed into the design of institutions in line with the above mentioned objectives and will facilitate the assessment of policy needs and outcomes in the field of the societal and economic inclusion of migrants and population of immigrant background. Support sustainable growth and job creation through a European industrial policy for cultural and creative industries including design.

- Research will support policies for inclusive growth and upward convergence via a strategy of social and economic investments, structural reforms and productivity enhancing policies in line with the European Pillar of Social Rights and the EU's policies on smart, inclusive and sustainable growth.
- Research will also assess the role of specific sectors as relevant, including cultural and creative sectors and the social economy, for today's social and economic transformations.
 - Similarly, activities will help reverse inequalities, increase equal opportunities and tackle social exclusion taking into account long-term trends and risks with a view to advancing the EU's employment, education and social inclusion policies. R&I will boost the EU's capacity to monitor perceptions of key socio-economic trends and better anticipate needs and developments. Such information is needed e.g. for strategies for inclusive education, training and lifelong learning for high value added skills, which can facilitate social mobility and economic growth.
- Another objective will be to assess the multidimensional impacts of globalisation and technology, including digitalisation and automation, on the future of work and skills needs, productivity, employment, taxation, welfare, social services and the public sector; in the wide variety of social, economic and territorial contexts in Europe.
- Gender equality in all social, political, economic and cultural domains shall be covered. Addressing intersections between gender and other social categories, such as disability, sexual orientation and ethnicity, will also be a focus.
- Equally, activities will facilitate the EU's response to new impacts of globalisation and economic competition with a view to fairness as well as economic and social sustainability and resilience (integrating a territorial dimension). The goal will be to strengthen resilience through shock absorption mechanisms including at EU level via fiscal, monetary, social protection, labour market and macro prudential policies.
- Activities will bring the benefits of digital transformation to education and training, by making optimal use of emerging technologies (such as AI, data analytics or blockchain) and by providing teachers and educators with the adequate skills, knowledge and awareness of opportunities.
- R&I will support the digital transformation and modernisation of public administrations and help them meet citizens' and other stakeholders' expectations regarding user-

centric/personalised service provision, including where service provision is threatened by social or spatial challenges.

- Activities in this R&I orientation will also support EU migration and mobility policies, both internal and external. Research will focus on analysing past and current dynamics of migration and integration, future trends and projections, societal impacts of migration of refugees and other migrants, and the effects of migration policies. It will help understand and address drivers and transformations underlying migration. Activities will contribute to strengthening mobility and migration governance in Europe and globally, by improving the quality of the data landscape and evidence-based knowledge

European Partnerships

HORIZON EUROPE CLUSTER 3

CIVIL SECURITY FOR SOCIETY

1. Global Challenges and their Drivers

This cluster has as its vision to support wider EU responses to security challenges i.e. to support ‘a resilient and more stable Europe that protects’.

2. EU Policy Objectives

This cluster will support implementation of EU policy priorities relating to security, including cybersecurity, and disaster risk management.

- R&I activities in relation to disaster risk management will support implementation of the Union Civil Protection Mechanism, the EU Adaptation Strategy as well as of the Sendai Framework for Disaster Risk Reduction (2015-2030) and the Paris Agreement, and related international processes such as IPCC and IPBES. In relation to CBRN-E incidents, R&I will support implementation of the EU CBRN and Explosives Action Plans.
- R&I activities in relation to protection and security will support implementation of relevant EU policies including those developed under the framework of the European Agenda on Security and the development of a Security Union. These include policies on integrated border management, the EU Action Plan on the protection of public spaces, policies and instruments on protecting critical infrastructure, and policies and instruments on fighting crime, including cybercrime and terrorism.
- R&I activities will support the EU Maritime Security Strategy and, as concerns EU maritime borders, integrated border management.
- R&I activities in relation to cybersecurity will support the cyber security and privacy policy of the Union, in particular the NIS Directive, the GDPR and the future ePrivacy Regulation.

R&I activities under this Cluster will support practitioners, law enforcement agencies and other authorities in ensuring the security of European citizens, infrastructures and assets in general.

This cluster will contribute to a stronger and more competitive EU security technology and industrial base. It will also support European strategic autonomy in capacities and services for security such as cybersecurity; cloud services; artificial intelligence; critical raw materials and components; EU space technologies and systems (e.g. Copernicus, Galileo, EGNOS GOVSATCOM and Space Situational Awareness).

Activities will support achievement of SDG 16 (peace, justice, rule of law) and other relevant SDGs.

3. Expected Impacts

The main impacts sought are to support implementation of EU policy priorities relating to security, including cybersecurity, and disaster risk management:

- improved disaster risk management and societal resilience, leading to reduced losses from man-made and natural disasters;
- improved management of air, land and sea EU external borders, leading to better monitoring of movements across external borders and reduction of illegal movements of people and goods across those borders;
- better protection of citizens from violent attacks in public spaces, through more effective prevention, preparedness and response while preserving the open nature of such spaces;
- improved security and resilience of infrastructure and vital societal functions, such as healthcare, law enforcement, energy, mobility, communication and logistics infrastructures/networks, so as to minimise disruptions including from hybrid threats;
- improved maritime security, including from man-made and natural disasters and from security challenges such as trafficking, piracy and potential terrorist attacks, cyber and hybrid threats, notably through better maritime surveillance and capability development;
- fighting crime and terrorism more effectively, particularly through better prevention of criminal acts and enhanced investigation capabilities notably as concerns cybercrime;
- cybersecurity and a secure online environment, with citizens, public bodies and companies empowered to protect their data and online activities.

Those desired impacts are further specified in the following section in relation to each priority.

4. Key R&I Orientations

Within this cluster, civil security research will be progressively framed under a capability development approach. This approach focuses R&I activities as a contribution (notably through technology) to fill gaps in capabilities. It is for policy-makers and practitioners to identify those gaps and resulting requirements, and in such a way that ensures they reflect national and the shared needs at EU level. The process for defining and implementing R&I activities in this cluster needs to recognise that Member States have the front line responsibility for security but cannot address transnational threats effectively acting on their own. R&I can support this process, including by improving cooperation and exchange of information, and by increasing knowledge about relevant human and societal factors. EU-level R&I to fill capability gaps reduces risks of fragmented approaches and promotes better use of standards and resources, thus increasing the impact of EU responses.

An integrated approach is needed so as to take into account short-term needs stemming from fast-changing security threats but also to promote an anticipatory culture to address longer-term scenarios of future threats and mega trends.

In the field of security research it is particularly important to **take account of human factors and the societal context**, and to ensure the respect of fundamental rights, including privacy and protection of personal data. Furthermore, improved knowledge of relevant human and societal factors can better achieve the desired impacts. In this context, the Commission intends to continue to require that applicants complete a ‘Societal Impact Table’ as part of the submission process.

Account will be taken of the **gender dimension**, notably as part of R&I relating to the human and societal context of security and of disaster resilience and response.

Availability of and access to threats, risk and resilience knowledge, preparedness scenarios and data needs to be enhanced to strengthen capacities to forecast and to respond, and with practitioners' involvement (e.g. knowledge centres and networks). This includes data sets representing simulated scenarios. If possible, specific European research infrastructures, including those of the European Strategy Forum on Research Infrastructures (ESFRI), contributing to the identified challenges will be harnessed and new capabilities will be developed as needed.

4.1 Disaster-resilient societies

This priority aims to deliver:

- Reduced losses from disasters, of both (i) human life and health and (ii) environmental, economic, material and immaterial damage, in particular in vulnerable groups and areas, including heritage sites.
- Improved disaster risk management, covering prevention, preparedness, response and recovery, including of future or cascading risks and multiple hazards. Better understanding of the disaster management cycle for incidents with a high impact but a low probability of occurrence (“Lo-Hi/HILP” events).
- Improved societal risk awareness, prevention and preparedness, including early warning and alert systems, leading to improved societal resilience to prevent, prepare and respond to natural and man-made disasters. Relevant communities are better involved in the development and implementation of plans supporting resilience, including for the evacuation of vulnerable populations.
- Improved response, including: coordination for cross-border disasters; integrated and interoperable technologies, tools and methods to support emergency procedures, developed with all actors; EU-level standards for response and emergency planning.
- Cross-sectoral and multilevel governance on disaster risk management at EU level which manages trade-offs in policy-making on civil protection, land management, agriculture and rural development, environment, climate and energy.
- Methodologies defined for ‘resilient by design’ infrastructure.
- Post-disaster recovery respects local communities’ aesthetic-historical-social values as well as quality standards for cultural heritage sites as a result of improved knowledge of human and societal factors.

a) chemical, biological, radiological, nuclear and explosive (CBRN-E) incidents

- CBRN-E risks are better understood.
- Better CBRN-E measurements, including standards and certification for detection equipment, better comparability of data, both within EU and beyond.
- Better preparedness for and response to incidents, including for: identifying and filling gaps in capabilities for response and in protecting first responders; capacities for detecting and evaluating threats and incidents; communication tools for first responders; detection and triage of victims.

- Better cooperation between relevant actors (e.g. law enforcement and civil protection authorities, military, health, industry, plant operators, regulators), including strengthening internal-external links (EU CBRN Centres of Excellence Initiative) and with key international partners (NATO, OPCW, Interpol).

b) climate-related risks and extreme events, such as fires, droughts, floods, heatwaves and storms

- Improved forecasting and understanding of climate change related risks and vulnerabilities, including their application within emergency planning and consequent improvements to response capacity.
- Improved adaptation to climate change impacts (both sudden and slow onset), including cascading and spillover effects. Improved science-to-practice knowledge exchange and use of sustainable, cost-effective and inclusive approaches, including nature-based solutions, to strengthen climate change adaptation.

Improved cross-border management, both within the EU and at wider transboundary levels, of new and emerging climate change induced risks and impacts.

c) geological disasters, such as earthquakes, volcanic eruptions and tsunamis

Better preparedness for and response after such events, including by improved civil protection capacities, including faster detection and evacuation of victims.

d) pandemics and emerging infectious diseases⁵⁴

- Earlier detection of outbreaks.
- Improved response, including European Pandemic Preparedness Plans⁵⁵ informed by scenario development, enhanced capacities in case of cross-border events through validating operational strategies and technologies in real-case scenarios.

4.2 Protection and Security

4.2.1 EU external borders

This priority aims to deliver (to support air, land and sea EU border management):

- EU border management priorities more effectively implemented as a result of improved knowledge about human and societal factors underlying cross-border threats.
- Enhanced interoperability and performance of relevant EU information systems. This will improve information exchange and analysis.
- Concerning persons in particular, whether crossing borders legally or illegally, capability gaps identified by the European Border and Coast Guard Agency are addressed.

⁵⁴ Activities in relation to pandemics and emerging infectious diseases will complement those undertaken under the cluster 'Health'.

⁵⁵ See the requirement for Preparedness Plans in Decision No 1082/2013/EU on serious cross-border threats to health, as well as the link with the International Health Regulations (2005).

- Development of tools and methods for Integrated Border Management, in particular to increase reaction capability and capacity for monitoring movements across external borders. This will improve risk-detection, incident response and crime prevention.
- Concerning goods in particular, capability gaps identified by EU customs are addressed.
- Improved detection of fraudulent activities at border crossing points and throughout the supply chain.

The European Border and Coast Guard Agency will be closely associated with relevant R&I activities, taking into account its central role – proposed by the Commission (COM(2018) 631) – in defining capability requirements for the European Border and Coast Guard.

4.2.2 Protection of public spaces⁵⁶

This priority aims to deliver:

- Improved security and public safety while preserving the open nature of urban public spaces, ensuring that citizens can continue their daily lives.
- Improved prevention, preparedness and response of urban actors, including city authorities, law enforcement authorities, public/private service providers, first responders and citizens, in response to threat of terrorist attacks in public spaces.
- Improved capacity to detect explosives, firearms and other weapons, and chemical, biological, radiological, nuclear (CBRN) materials being brought into public spaces.
- Improved effectiveness of mitigation measures including through strategies to reduce vulnerability and enhance the resilience of potential targets.

4.2.3 Security and resilience of infrastructure and vital societal functions⁵⁷

This priority aims to deliver:

- Improved risk assessment, including of interdependencies and cascading risks.
- Improved security and resilience of basic societal functions such as healthcare, law enforcement, energy, mobility, communication and logistics infrastructures and networks (both physical, on ground and in space, and digital), so as to minimise societal disruptions.⁵⁸
- Better prevention, detection, response, mitigation of consequences and faster recovery of service performance levels, including leveraging the potentials of big data and artificial intelligence.
- Better understanding and detection of hybrid threats and improved response.

⁵⁶ This priority also relates to the intervention area 4.1 Disaster-resilient societies.

⁵⁷ This priority also relates to the intervention area 4.3 Cybersecurity.

⁵⁸ Activities in relation to energy, mobility and logistics infrastructures and networks will complement those undertaken under the cluster ‘Climate, Energy and Mobility’.

- Improved tools for security actors (police, relief workers, disaster managers, crisis managers) e.g. communication, surveillance, robotics.

4.2.4 Maritime security

This priority aims to deliver:

- Capability gaps identified by the EU Maritime Security Action Plan are addressed, including those related to risk awareness and management of EU critical maritime infrastructure (with regard to man-made and natural disasters, accidents, climate change and security challenges and threats such as piracy and armed robbery at sea, cyber, hybrid and CBRN threats and potential terrorist attacks), border protection and coast guard functions.
- Capability gaps identified in the EU Maritime Security Research Agenda are addressed, including those related to cybersecurity, interoperability and information sharing, autonomous systems, networking and communication systems, and multi-purpose platforms.
- Improved maritime security, notably through better maritime surveillance.

4.2.5 Fighting crime and terrorism

This priority aims to deliver:

- Improved prevention, investigation and mitigation of impact of criminal acts, including of new/emerging types (such as those resulting from digitisation), as a result of improved knowledge and its operational use by EU law enforcement agencies and civil society organisations of human and social aspects of relevant societal challenges, such as violent radicalisation, child sexual exploitation, trafficking of human beings or cybercriminality, including support to victims.⁵⁹
- In order better to tackle crime, including cybercrime and terrorism as well as the different forms of serious and organized crime (such as smuggling, money laundering, counterfeiting of products, environmental crime or illicit trafficking of cultural goods⁶⁰):
 - better prevention of criminal threats, due to improved or new technologies, tools and systems (including digital tools, e.g. artificial intelligence), including improved capabilities to analyse in near-real-time large volumes of data to forestall criminal events, or to combat disinformation and fake news with implications for security;
 - enhanced criminal investigation capabilities for law enforcement agencies, including forensics, improved capabilities to manage big data and to investigate cybercriminal activities, and improved cross-border exchange of evidence.

⁵⁹ Activities in relation to smuggling and trafficking of persons will complement those undertaken in relation to migration under the ‘Social and Economic Transformations’ priority of the cluster ‘Culture, Creativity and Inclusive Society’.

⁶⁰ Activities in relation to trafficking of cultural goods will complement those undertaken under the ‘Cultural Heritage’ priority of the cluster ‘Culture, Creativity and Inclusive Society’.

- Increased knowledge of counter-terrorist practitioners about the continuously evolving methods related to dangerous chemicals, and the development of technologies to counter and respond to incidents with them.
- Improved capabilities for cross-border law enforcement data exchange and cooperation, and improved law enforcement working methods.

4.3 Cybersecurity

This priority aims to deliver:

- Citizens, public authorities and companies, including SMEs, are empowered to protect their data and online activities notably when using social media.
- Resilient critical infrastructure, both private and public, better protects the Digital Single Market and the digital life of citizens against malicious cyber activities, including via non-digital fall-back technology and appropriate levels of systemic redundancy.
- Stronger European cybersecurity industrial R&D capacities are supported and their strategic autonomy vis-à-vis foreign technology is enhanced.
- The effective use of:
 - innovative digital technologies, including self-healing, artificial intelligence, cryptography, massively distributed computing and storage, quantum and post-quantum increase data security.
 - digital technologies, including security-relevant innovations in the area of governance of algorithms, coding architecture, and programming languages foster the right to privacy, protection of personal data, and the protection of fundamental right in the digital age.
- Cyber-attacks are better managed and coordinated, including thanks to a more effective response to incidents and better impact management.
- Emerging threats against democracy and European society, including electoral meddling, fake news, digital attacks and online manipulation, are effectively addressed.⁶¹
- The architectural principles of ‘security-by-design’ and ‘privacy-by-design’ are implemented in digital technologies and their applications, such as 5G, industry 4.0, artificial intelligence, Internet of Things, blockchain, quantum key distribution, mobile devices and connected cooperative and autonomous mobility, energy.

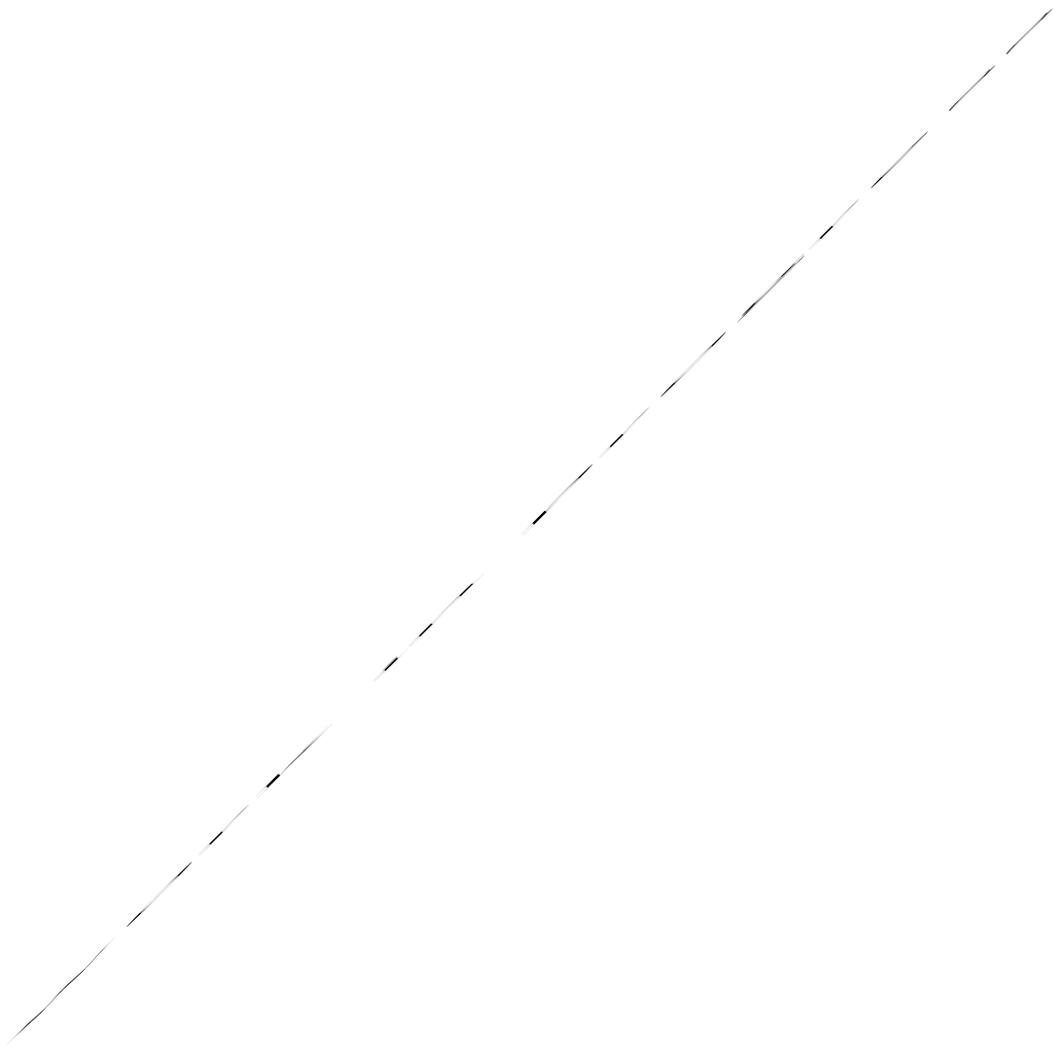
To be delivered thanks to the Cybersecurity Competence Centre and Network of National Coordination Centres (Commission proposal COM(2018) 630)⁶² and in coordination with the Digital Europe Programme.

⁶¹ Relevant activities will complement those undertaken under the ‘Democracy and governance’ priority of the cluster ‘Culture, Creativity and Inclusive Society’.

⁶² The proposed Regulation is still under discussion.

European Partnerships

[The Commission is not at this stage suggesting any new partnerships under this cluster.]



HORIZON EUROPE CLUSTER 4

DIGITAL, INDUSTRY AND SPACE

1. Global Challenges and Their Drivers

Digitisation and technological progress shape all sectors of the economy and society. They transform the way industry develops and produces new products and services, as well as the way we live, work and learn, and are central to any sustainable future. To succeed in this transition, research and innovation needs to target global leadership and autonomy in strategic value chains,⁶³ enable production and consumption to respect the boundaries of our planet and maximise the benefits for all parts of society

Sufficient positive changes on these fronts can only happen by facilitating technological progress and steering digital and industrial transformation. EU industry, including both SMEs and large companies, therefore needs continued EU support for the development and uptake of smart and clean technologies. However, the EU cannot do this alone. Partnership initiatives could help leverage the necessary additional private and public funding and align research and innovation priorities across Europe.. There are **three main challenges**:

- (i) Although Europe has been a leading player in research and innovation across a number of industrial sectors, this position is more than ever at stake and eroding. Reliance on imported key technologies and raw materials is compromising Europe's autonomy. Europe's industry faces fierce **global** competition, combined with difficulties in financing high-risk investments in complex technological areas, including digitisation and circularity. It is also hampered by ageing infrastructures, including machinery that is not ready for digitisation and plants not fit for a fully circular and climate neutral industry. Long investment cycles are needed in key EU industries, notably the energy-intensive industries.

Key facts and figures:

- ➔ Industry, including manufacturing, processing and construction, makes a significant contribution to the European economy, providing 36 million jobs, although this has steadily declined. Manufacturing in particular generates EUR 32 billion of added value, a share of around 16% of total added value.
- ➔ While Europe is one of the world largest markets for **digital products and services**, the contribution of European industry and businesses to the worldwide digital supply

⁶³ The Commission unveiled preliminary recommendations of the expert group on strategic value chains, the Strategic Forum for Important Projects of Common European Interest, to prepare coordinated action and investment to strengthen key strategic value chains. For instance, low-carbon Industry and Industrial Internet of Things have their centre of gravity in this cluster. https://ec.europa.eu/growth/content/stronger-and-more-competitive-eu-industry-president-juncker-open-2019-eu-industry-days_en

chain has shrunk gradually over the past 20 years⁶⁴. Most recently (2017-18), EU companies reduced their global R&D share in ICT industries by more than 8%⁶⁵.

- ➔ Space technologies, data and services have become indispensable in the daily lives of European citizens: when using mobile phones and car navigation systems, watching satellite TV, enhancing weather forecast and improving emergency services. The generated value from **space related activities** is estimated between EUR 46 to 54 billion representing a share of 21% of the worldwide business. In addition, the capacity to access and use space is a strategic asset for Europe and its Member States, which impacts many other sectors,⁶⁶ and opens up many business opportunities for early-stage and high-tech companies, especially in combination with digital technologies and other sources of data. The EU must make the most of these opportunities by fully exploiting the potential of its space programmes Copernicus, EGNOS and Galileo.
- ➔ Research and Innovation are recognised as an important source of economic growth and competitiveness, but there is an **urgent need for more investments** in Europe, in particular in industry. Industry accounts for 64% of private sector R&D expenditure and for 49% of innovation expenditure.⁶⁷ The R&D conducted within the business enterprise sector in the EU was equivalent to 1.36 % of the EU-28 GDP in 2017, significantly below the EU's "2%" target for the private sector and lower than in South Korea (3.27%), Japan (2.57%), Switzerland (2.39%) and the United States (1.97%).⁶⁸ In digital for example R&D intensity is about 5% as opposed to 12% in the US and 11% in Japan.⁶⁹
- ➔ The EU shows higher shares of R&D in medium-tech sectors (circa 40%) as compared to USA and China (circa 20 and 30%), while lower shares of R&D in high-tech sectors are seen with respect to USA and China (circa 75 and 43%). There is a need to integrate horizontal industrial and innovation policies with sector/technology specific ones, to promote the industrial transformation towards the knowledge economy by reinforcing the presence of high-tech sectors, while fostering the modernisation of low- and medium-tech sectors and their capacity to absorb new technologies.
- ➔ EU public investment in R&D in digital technologies is 40% less than in the US; and in critical areas, such as Artificial Intelligence (AI), public and private investments in

⁶⁴ *Etude sur l'écosystème électronique: Vue d'ensemble, développements futurs et position de l'Europe dans le Monde*, 2018 DECISION Etudes & Conseil

⁶⁵ 2018 EU Industrial R&D Investment Scoreboard <http://iri.jrc.ec.europa.eu/scoreboard18.html>

⁶⁶ The European space economy, including manufacturing and services, employs over 230 000 professionals in a large number of SMEs. Its value was estimated at EUR 46-54 billion, representing around 21% of the value of the global space sector. It captures around 20 % of the open world markets, and a dynamic downstream services sector. Satellites provide immediate information in support of numerous Union policies.

⁶⁷ Re-finding Industry. Report of the independent HLG on Industrial Technologies, 2018.

⁶⁸ Non-EU28 countries figures are from 2015. EUROSTAT database

⁶⁹ 2012 PREDICT REPORT

<http://is.jrc.ec.europa.eu/pages/ISG/documents/OnlineversionFINALPredict2012withnumbersv2.pdf>

the EU are 4 times less than in the US. China set up a strategy plan⁷⁰ to support an AI industry worth 150 b\$ including the development of AI chips. This complements the 2025 plan, which strives to secure its position as a global powerhouse in high-tech industries, and focuses heavily on intelligent manufacturing in 10 strategic sectors. The strategy seeks to raise the domestic content of core components and materials to 40% by 2020 and 70% by 2025.⁷¹ In Space, the EU governments' investments of EUR 8.2 billion in upstream space programmes are well under half of the NASA budget, and probably under one third of the total US space budget.

- ➔ SMEs tend to implement new technologies at slower rates than larger companies. For instance, 36% of companies with 50-249 employees use industrial robots, compared to 74% of companies with over 1000 employees. Only a fifth of EU companies are highly digitised.

(ii) Europe's industry can adapt to **planetary boundaries**, through a transformation that will allow it to cope with a scarcity of resources, including energy; and to reduce its large share of greenhouse gas emissions, pollution and waste.

As a major user of natural resources, industry needs to reduce its carbon and materials footprint in order to ensure sustainability in the circular economy and to reach Paris Agreement targets. The great acceleration in global resource consumption has increased environmental pressures beyond sustainable levels.

Key facts and figures:

- ➔ Industry is the third biggest contributor to greenhouse gas emissions. The latest increase of CO₂ emissions is of particular concern, considering the efforts needed to comply with the Paris Agreement and a climate-neutral economy by 2050. Hence an overhaul of business models as well as disruptive technologies are needed.^{72 73}
- ➔ The global energy consumption by industry grew 1.3% each year on average between 2010 and 2016. In the EU28, between 2005 and 2016, final energy consumption decreased by 7.1% (0.7% annually) in all sectors, particularly in industry (16,4 %).⁷⁴
- ➔ According to the International Energy Agency (IEA)⁷⁵, global industrial CO₂ emissions in 2016 amounted to 8.3 GtCO₂, or 24% of global emissions. In terms of EU sectors, steel, cement and chemicals dominate industrial emissions. In a "business as usual" baseline scenario, EU emissions from these three sectors could amount to 546 MtCO₂ per year by mid-century. To achieve climate-neutrality in 2050, significantly larger investments in deep decarbonisation technologies are needed.

⁷⁰ New Generation of Artificial Intelligence Development Plan

⁷¹ Made in China (MIC) 2025

⁷² A Clean Planet for All, COM(2018)773 final

⁷³ The Club of Rome Climate Emergency Plan, December 2018, <https://www.clubofrome.org/2018/12/03/the-club-of-rome-launches-the-first-climate-emergency-plan/>, "...global carbon emissions must be cut by half by 2030, to zero by 2050. This is an unprecedented task, requiring a reduction rate of at least 7% annually; no country has to date achieved more than 1.5%."

⁷⁴ European Environment Agency [database](#).

⁷⁵ <https://www.iea.org/tcep/industry/>

These investments are estimated to be around an additional 5,5bn euros per year for the above mentioned sectors, an 88% increase compared to the baseline scenario.⁷⁶

- ➔ The rapid expansion of the digital sector has environmental consequences, including the considerable increases in extraction of critical raw materials, and energy consumption from servers and other equipment.

(iii) Developments in industry and in enabling technologies have the potential to enhance **social inclusion**. Workers, regions and societies are faced with extremely fast transformations, including the impact of digitisation and climate change.

The rapid technology diffusion, its impact on labour market, nature of work, skills mismatches and increasing wealth concentration are other challenges in Europe. Other **concerns regarding new technologies** include trust and ethical considerations. All the new approaches must also engage citizens, workers and consumers, focusing on training and familiarity with technology. This is also necessary to make the new climate-neutral and circular economy approaches and products work.

Key facts and figures:

- ➔ There are substantial variations in the level of economic activity and labour market performance across Europe, including in their technological specialisation and R&D investment. Long-term economic and industrial decline, low levels of education and a lack of local employment opportunities emerge as key drivers of the anti-EU vote.⁷⁷
- ➔ Evidence indicates a considerable accumulation of wealth by a small section of society, as others face increasing hardship and a widening inequality gap. The Commission's Ethics Group warns that new forms of work bring unparalleled flexibility but also precariousness; and exposes the limitations of existing social models to guarantee decent livelihoods for many Europeans.⁷⁸
- ➔ Due to the deployment of new technologies and automation, there is an increase in the number of high-skilled jobs. However, around 20% of European workers judged their current ICT skills insufficient. The highest skill mismatches are in occupations related to ICT, manufacturing and construction. A third of the EU labour force has an insufficient level in digital skills.⁷⁹ The lack of skilled individuals and talents risks to slow down investments. For instance, 9 out of 10 manufacturers are struggling to find the skilled workers needed. Similarly, more than half of companies looking for ICT specialists report difficulties in recruiting them. Hence, there is a need to reform the current educational system, and better anticipate and develop skills to equip the labour force with appropriate skillsets.

⁷⁶ Industrial Transformation 2050, Pathways to Net-Zero Emissions from EU Heavy Industry, Material Economics and ECF, 2019

⁷⁷ [The Geography of EU Discontent](#)

⁷⁸ [Future of Work, Future of Society - European Group of Ethics in Science and New Technologies, December 2018](#)

⁷⁹ Digital Economy and Society Index, <https://ec.europa.eu/digital-single-market/en/desi>

2. EU Policy Objectives

Against this background, the overarching vision behind the proposed investments is **a European industry with global leadership in key areas, fully respecting planetary boundaries, and resonant with societal needs** – in line with the renewed EU Industrial Policy Strategy.⁸⁰ Three objectives will be pursued in synergy with other EU instruments and initiatives:

(i) Ensuring the **competitive edge and autonomy of EU industry**.

Key enabling technologies, many of which are digital, and new services offered by digital and space technologies, will help revolutionise both industry and society and reinforce Europe's global industrial leadership. Developing and mastering these technologies will give EU industries the competitive edge they need for industrial leadership on global markets; and promise bringing innovation and market breakthroughs to achieve a circular, resource efficient and climate-neutral EU economy.

In a globalised world of heightened uncertainties and volatile geopolitical interests, it is essential to secure and assert European autonomy in a number of strategic technology areas and value chains, while continuing cooperation and exchanges with third countries.

To be autonomous the EU must tackle missing segments in key strategic value chains. To begin with, it must ensure a secure and sustainable supply of raw materials, maximising the value of its resources and materials. Examples are batteries, low-carbon industry, space critical components, smart connectivity platforms and microelectronics.

Another vital component of the EU's strategic autonomy is technological non-dependence, to safeguard security of supply and European industry's ability to export its products as part of a global value chain. For the EU Space industry for instance, non-dependence is key for a number of components used for satellites and launchers.

To maximise impact, we must ensure that all European enterprises, including small-and medium-sized enterprises and start-ups, have access to the technologies and data they need, by promoting an **ecosystem of technology infrastructures**, catering for industry, including SMEs and start-ups; and by establishing a European data ecosystem, in conjunction with the Digital Europe Programme.

(ii) Fostering **climate-neutral, circular and clean** industry: the pressing need to tackle a number of sustainability challenges, notably climate change, creates opportunities for developing new technologies allowing industry to reduce energy consumption, protect the environment and enable a circular economy. Europe should take the lead in this approach.

The breakthrough technologies and solutions to be developed in this cluster⁸¹ will contribute to bring about climate-neutral EU industries by 2050, thereby delivering on the 2050 Long-Term strategy, calling for a climate-neutral Europe by 2050;⁸² and foster

⁸⁰ Investing in a smart, innovative and sustainable Industry A renewed EU Industrial Policy Strategy, COM(2017)479.

⁸¹ including low-power processors and computing architectures

⁸² A Clean Planet for all – A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, COM(2018)773

a circular economy.⁸³ Future factories will be climate-neutral, resource-efficient and fully integrated in the circular economy. The climate-neutral and circularity ambitions will reinforce one another.

Earth observation from space, combined with advances in computing, analytics and artificial intelligence, will bring invaluable information on the climate of our planet and its environment that will guide the development of mitigation measures.

- (iii) A **major contribution to inclusiveness**: From the outset we must involve and empower workers, consumers and firms to make sure that they have access to, and take up, these technologies (reflecting gender and other diversity issues where appropriate). *In conjunction with other programmes and initiatives*, there must be adequate support for the development of skills and the development of regions – ensuring a socially fair transition not leaving anyone behind. We must also pay due regard to safety and the impact of technologies and industrial transformation on people and societies.

The EU technology developments will follow a **human-centred approach**, going hand in hand with European social and ethical values, social inclusiveness, and the creation of sustainable, high-quality jobs including through social innovation. For example in Artificial Intelligence developments will follow the key requirements⁸⁴ for trustworthy AI identified by the High-Level Experts Group established by the Commission.

The interaction of science, technology, social sciences and humanities will be important in this respect, so will be the input of creative sectors and artists to sustainable inclusive innovation and to human-oriented technologies⁸⁵

In addition to this cluster, the other clusters will also develop and apply key enabling and emerging technologies, as part of a common strategy to promote the EU's industrial and social leadership.

3. Expected Impacts

By 2030, industry will be providing one out of four jobs, having set the transition to climate-neutrality before 2050 on a solid ground.

In key strategic value chains⁸⁶, there are sufficient European players present to secure EU autonomy and with some leadership in some key enabling technologies

Input from the activities under this Cluster will inform up-skilling training programmes, and lead to appealing and creative jobs across Europe.

More specific impacts are outlined under the specific R&I priorities that follow.

⁸³ Closing the loop - An EU action plan for the Circular Economy, COM(2015)614

⁸⁴ Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Building Trust in Human Centric Artificial Intelligence (COM(2019)168)

⁸⁵ www.STARTS.eu

⁸⁶ https://ec.europa.eu/growth/content/stronger-and-more-competitive-eu-industry-president-juncker-open-2019-eu-industry-days_en

4. Key R&I Orientations

Key R&I Priorities are grouped in two general categories: (I) Enabling technologies ensuring European leadership and autonomy; and (II) Accelerating economic and societal transitions (these will be complemented by priorities of other clusters).

I. Enabling technologies ensuring European leadership and autonomy

4.1 Manufacturing Technologies

Innovative manufacturing technologies will play a key role in the transition to sustainable prosperity for all, create strategic advantage and reinforced competitiveness in terms of increased productivity, enhanced job quality and reduced carbon footprint. Priorities include:

- Increasing the rate of new, value-added job creation through technology-driven innovations in design, engineering, logistics and end-of-life management; innovative business approaches, such as customisation and product-service systems; and applications of emerging technologies such as AI and human-robot collaboration that provide the basis for improving the quality of jobs.
- Strengthening and creating value chains based on digital industrial platforms, benefitting the production sectors from automotive and aerospace to health and food processing.
- Enhancing productivity via the digital transformation to realise lower production costs and shorter innovation cycles, new business models, higher quality products and enhanced workplace skill-sets. more circular economy, with products reused in new, innovative value chains through “zero-waste” manufacturing, de- and re-manufacturing, including smart recycling, re-use of raw materials, repair and refurbishment.
- Developing bio-integrated manufacturing through the combination of disciplines including fundamental research in biology, engineering, machine learning and manufacturing as well as the adoption of processes such as biomachining, biomimetics, biomechanics, and bio-inspired digital manufacturing.
- Developing innovations enabling a “new way to build”, for construction with lower environmental footprint, through modularisation, digital technologies, circularity and advanced materials, as well as standards and safety.

These investments should turn manufacturing into a human-centred, highly flexible and sustainable enterprise, providing attractive jobs, even in city centres; supporting leadership in strategic value chains; and offering new products for new markets.

4.2 Key Digital Technologies

The opportunities from digitisation are immense and are driven by advances in technology, applications and services around a set of main tracks.

At the heart of digital transformation is the continuous progress in the key underlying electronics and photonics components, software technologies and connectivity platforms. With the scaling of mainstream nanoelectronics technology coming to an end, the main challenges ahead include innovative digital components and devices based on new materials

(such as graphene), low-power electronics and alternative processing concepts, like neuromorphic, that map cognitive processes into electronic circuits, and quantum information processing. These innovative approaches unfold a new era of digital applications providing unprecedented levels of computing power, trust and security, as well as high precision sensing and low energy consumption.

These developments will provide the basis for new computing and programming concepts such as edge computing, and for advances in modelling and simulation (e.g. digital twins). They are bringing the benefits of digital innovations, notably Artificial Intelligence and big data analytics, to all types of products and services from connected and autonomous vehicles to health equipment, novel materials and drugs, and smart energy systems.

Europe can capitalise on its recognised strengths in reliable cyber-physical systems, in embedded and professional software and complex systems to seize the wide range of opportunities ahead.

The EU's current strong industrial value chains (e.g. automotive, aerospace, machinery and agro-food) are increasingly dependent on these core digital components and software.

4.3 Advanced Materials

New materials are the key to virtually every global challenge. To realise their potential, we must be able to develop advanced and sustainable materials with the required properties, often inspired by biological systems; and to make sure that the widest possible community of users will be able to capitalise on them.

The materials development cycle is long and entails steps such as characterisation, modelling, upscaling and engineering, including in industrial environments. The aim is to develop materials that are functional, safe, sustainable and competitive, serving needs in global challenges and respecting regulatory standards. In particular they will need to conform to the circular economy. A coherent approach to life-cycle methodologies will assure developing and monitoring a cradle-to-cradle approach, supporting further the principle of the European eco-label too. They will also need to be taken up in industrial value chains; the relevant choices may be eased through a greater availability of evidence.

Integrating creativity into product design and development, through the involvement of creative professionals to support an “innovative materials by design” approach, is an efficient way to answer the growing consumer demand for innovative products combining functionality with aesthetics, and innovative solutions along the circular materials cycle.

To enable uptake by industry, especially SMEs and start-ups, there is a need for an **innovation ecosystem of materials technology infrastructures**, including open innovation testbeds and pilot lines. These will cover all relevant enablers and services needed for innovation based on new materials. In addition to responding to industrial needs, they will reduce the technological risk of innovative materials and products, thus attracting more investors, and cut the time to market.

These investments should lead to multifunctional and safe new materials, comparable to living organisms, embedded in strategic value chains and radically reducing environmental footprint.

4.4 Emerging Enabling Technologies

Fascinating technologies that we could not imagine even a few years ago hold the potential to revolutionise the way in which we live and work. New enabling technologies will be needed as current ones become obsolete or clash with planetary boundaries. By exploring the potential of such technologies at an early stage, Europe can secure leadership in key enabling technologies of the future.

The objective of these activities will be to facilitate the early development (at low TRLs) of a limited number of new enabling technologies and feed the innovation pipeline. This will be done by scouting for transformative research themes, building also on the results of Pillars I and III; and by exploring their potential for society, the environment and industry.

Success depends on the combination of disciplines, from fundamental research in biology to engineering, manufacturing and computer learning. Social sciences and humanities will also play a role in envisaging the transformation pathways.

Examples include:

Future and emerging materials by design: A wide range of global challenges call for new materials by design, which are functional, safe, recyclable and sustainable (e.g. new plastics and polymers, catalysts, coatings and membranes).

Enhanced information-based technologies inspired by the laws of nature and biology: an improved fundamental knowledge of how living beings function will enable new applications of biotechnology supporting sustainability.

The convergence of the “digital and the physical” and entirely new forms of digital technologies like computational modelling of processes such as metabolisms or the dynamics of cell differentiation. They will bring long-term benefits for our citizens while transforming industrial processes for a circular and sustainable economy (e.g. progression of neuro-degenerative diseases, the chemistry of photosynthesis, climate change and environmental impacts, or the dynamics of social behaviour).

4.5 Artificial Intelligence and Robotics

Driven by higher computing power, availability of large amounts of data (the essential raw material for innovation, competitiveness and growth) and progress in algorithms, smart devices and smart robots, Artificial Intelligence (AI) is shaping up as one of the most strategic technologies of the 21st century. The way we approach AI will define the world we live in.

Amid fierce global competition, a collective and decisive EU Research and innovation agenda for AI will be instrumental in bringing its benefits to all our citizens and businesses whilst ensuring high ethical standards.⁸⁷ The EU must therefore promote the adoption of principles and global standards which will ensure an ethical approach to the development and use of technologies at both EU and international level.

⁸⁷ Communication 'Artificial Intelligence for Europe' & Coordinated Plan on Artificial Intelligence (COM(2018) 795 final)

Citizens will experience the advantages of AI in routine tasks from booking holidays to augmented reality supporting them in specific tasks. Medical doctors will ask the support of powerful data-intensive machine learning to support their diagnostic and therapy decisions. Firefighters will get the support of robots to approach hazardous intervention zones.

The introduction of AI and autonomous behaviour in complex, safety- and time-critical systems, such as those used in large transport networks, avionics, health or industrial applications, is a technological challenge but also a significant business opportunity for which Europe has a competitive advantage. Europe also needs to deploy a human-centric, ethical and trustworthy AI, which will be crucial for its acceptance, and a trademark for AI developed in Europe.

The challenges in AI and Robotics (embodied AI, one of European strength AI) include foundational research improving algorithms, achieving explainable AI (transparent decision making), adaptive learning, and improving smart, collaborative, safe and efficient robots and autonomous systems, as well as applied research to demonstrate progress for applications needs. Common AI platforms and reinforced collaboration among researchers are expected to combat fragmentation.

These investments should lead to significant European advances in AI, characterised by increased societal engagement and human-centred approaches.

4.6 Next Generation Internet

The Internet has become the critical infrastructure as many social and economic activities depend on it.

The Internet of today has significant limitations, in particular vulnerability to concentration of market positions from devices to networks. Concentration in few powerful providers generate potential threats of user lock-in. Breaches of citizen's security or privacy, lack of accessibility, lack of user control of their data, and manipulation or disinformation are some of the major challenges to be tackled.

Being a global network of networks Europe has no choice but to invest further in R&I to be a leading force shaping its technological and market development.

The next generation Internet (NGI) initiative will address growing societal and political concerns and service needs, with a human-centric trustworthy internet enabling full connectivity and accessibility and collective intelligence (people, processes, data, content and things) and safeguarding core European values. It aims at supporting an autonomous European Internet supply chain, which can meet the future industrial and societal needs establishing Smart Networks and Services and Content platforms (including Internet of Things and cloud). It builds on a comprehensive strategy including a technology push and an application/ market/ end-user pull, and composed of technological layers with different time to market cycles.

Interactive Technologies, including immersive technologies and language technologies, will allow for a more inclusive, user-oriented/driven and innovative use of computers, machines and the Internet.

4.7 Advanced Computing and Big Data

Today, Europe critically depends on foreign supercomputing technologies that are key for scientific and industrial innovation, and its supercomputing supply industry provides only around 5% of supercomputing resources worldwide, whereas Europe consumes around 30% of these resources.

As transistor-based computers are reaching physical limits, the next generation of computing capabilities will be developed based on disruptive concepts, technologies and paradigms.

Europe has to be in the forefront of inventing the next generation low power processors and accelerators, integrate them in novel computing architectures and hybrid/modular systems to address future general purpose and/or specific applications.

Examples include R&D into novel neuromorphic architectures, quantum computing components, 3D and/or interposer/chiplet computing architectures, aiming to deliver the significant improvements of computational capability, performance and energy efficiencies required.

Combined with those advances, R&D will be also required for co-designing software, algorithms, programming models, simulations and tools for their integration in novel computing systems. These could be used for supporting the development of large-scale and industry-led pilot applications targeting key industry sectors, but also for public services like weather forecasting and climate modelling.

Further R&D efforts will also be required for advancing the state-of-the-art of extreme performance data analytics and prediction methods that enable the processing of Big Data - increasing volumes and streams of data that arrive from numerous sources at rates that are growing too fast for traditional computing methods.

While the abundance of data is a core element for computing complex problems and solutions, it may conversely create problems, in particular as regards the protection of personal and sensitive data (e.g. commercial data, trade secrets, health data...) that need to be protected by privacy-preserving technologies respecting the rights of data subjects and content creators.

In the same vein, some complex problems can only be computed and solved with a sufficient critical mass of data that may only exist in isolated silos that need to be connected. To ensure that diverse data from different sectors and of different types can be seamlessly combined and exploited across sectorial and national borders, methodologies and tools are needed to ensure interoperability and to keep track of the provenance, quality and completeness of data sets.

Furthermore, sustainability issues posed by digital technologies should be taken into account, notably when it comes to the energy efficiency of computing, which should be improved by several orders of magnitude.

These investments should lead to Europe relying on its own high-performance computing technologies.

4.8 A globally competitive space sector reinforcing EU autonomy

R&I actions will foster the competitiveness of space systems in particular for high throughput telecommunication and high-resolution earth observation. Digital and automated industrial

processes will enable seamless manufacturing for the production of cost effective constellations. In the longer term, hybrid, smart and reconfigurable satellites will be assembled and serviced directly on-orbit, with a de-orbiting capacity.

EU autonomy in accessing and using space will be reinforced with new concepts such as reusability of launcher components, low cost, high thrust and green propulsion, micro launchers, new types of payloads and space routes. Launch opportunities will be made available for in-orbit validation (“IOV”) and in-orbit demonstration (“IOD”) to de-risk new technologies, concepts and applications. These will be operating from modern and flexible launch facilities.

EU-funded research will also contribute to critical technologies, space science and missions and synergies with non-space sectors will be promoted.

II. Accelerating economic and societal transitions

4.9 Circular Industries

In a circular economy, the value of products, materials and resources is maintained for as long as possible and waste is minimised. The EU Circular Economy Action Plan⁸⁸ includes a wide range of initiatives for a sustainable, low-carbon, resource efficient and competitive economy. It also relies on research and innovation through the entire life-cycle to prevent new and larger waste streams and to tackle scarcity of resources, and price volatility. Also needed are solutions to increase material efficiency and recover the economic value of waste streams, while radically decreasing their environmental footprint. Priorities include:

- Design of circularity enabled products, implementation of circular supply chains and systematic cradle-to-cradle life cycle assessment both for new and existing products;
- Product life extension through predictive maintenance, repair, re-use, and refurbishment leading to value loops at European scale;
- Advanced solutions and conditions for the sustainable exploration, extraction and processing of raw materials; and also their substitution, recycling and recovery in industrial symbiosis settings;
- New automated technologies to sort, dismantle and remanufacture or recycle products; and efficient processes to handle mixed waste sources;
- Digital and industrial technologies like robotics, artificial intelligence, and digital platforms for energy intensive industries leading e.g. to fully fledged cognitive plants

Circular approaches need to be systemic, connecting people, products and systems. The focus will be on sectors, products and materials that have the highest impacts and the greatest potential for enhanced circularity.

These investments should reinforce European autonomy, through access to a sustainable and affordable supply of raw materials, in particular critical raw materials (through substitution, resource efficiency and better recycling); and reduce the dependence on overseas handling and processing of municipal and industrial waste.

⁸⁸ COM(2015)0614

4.10 Low-carbon and Clean Industries

Energy-intensive industries have a central role in the EU's industrial value chains. Heavily reliant on energy and non-energy raw materials, they will need to supply products with zero net emissions for downstream manufacturing. Deep decarbonisation calls for breakthrough technologies in all major emitting industrial sectors, in terms of: the underlying production processes (e.g. for steel, cement, chemicals); substitutes for carbon-intensive products; and decarbonised energy and feedstock.

By 2030, Europe's regions should benefit from entirely new types of industrial plants producing sustainably with zero greenhouse gas and polluting emissions and zero waste while being globally competitive.

The required technologies include process and heat electrification, switch to decarbonised energy and feedstock, CO₂ capture and usage, catalysis and artificial photosynthesis, waste heat recovery, and materials for re-use and recycling, all of which need to be developed and demonstrated in industrially relevant or operational environments before the first market deployment in the EU.

Industries will need to coordinate innovations and investments in clean energy systems, with a much higher share of renewables, far beyond what is already foreseen for 2030 (32.5%). A closer integration is needed across value chains, giving rise to new business models, processes and technologies in which waste and emissions would be either avoided or transformed into valuable resources for new innovative processes and industries. Co-located industrial plants, which can adapt their production to fluctuations in energy and resource flows, would ensure flexibility in energy and feedstock utilisation, including through industrial symbiosis amongst adjacent plants.

A closed-loop system, based on complex flows of resources, energy and information, would be supported, including through artificial intelligence-based technologies. Long-lasting arrangements are needed with renewable energy and storage providers to develop the necessary capacity, reduce security of supply risks and channel resources where they are most needed. These approaches also call for new business models, skills, and financial solutions; and need to be developed in conjunction with the priority 'support industrial facilities in the energy transition' under Cluster 'Climate, Energy and mobility'.

By 2030, these investments should lead to a large set of industrial plants in several regions, with zero net emissions of greenhouse gases, zero waste and zero polluting emissions - and by 2050, to factories that are climate-neutral, resource-efficient and fully integrated in the circular economy.

4.11 New services from Space for the EU society and economy

R&I activities will prepare for the next generation and applications of European Global Navigation Satellite Systems (Galileo/ EGNOS) to make intelligent mobility, connectivity and infrastructures a reality, whilst ensuring a non-dependent and sustainable supply chain, and integration with other technologies such as 5G.

Innovative applications will be developed for European and global uptake for the **European Union** Earth Observation System (Copernicus), in areas such as climate mitigation, monitoring GHG, environment, including polar regions, and security.

Further developments in sensors technologies and data processing will be supported as well as new services for space traffic management and research on space weather and near Earth

objects necessary to ensure the security of critical infrastructure both in space and on Earth for **Space Situational Awareness (SSA)**.

R&I activities will support user equipment and system solutions for space and ground infrastructure for **Satellite communications for EU governmental actors (GOVSATCOM)** as well as citizens and businesses.

These investments should lead to globally flexible, reconfigurable and competitive space assets and services, which can be tailored to evolving customer needs.

European Partnerships

Considering that Europe's industry is investing less than its global competitors, in particular in high-tech areas, and taking into account the need to accelerate the industrial transformation to climate-neutral and circular industries, this cluster will be instrumental in mobilising industry and leveraging greater public and private investment towards common goals.

Partnerships⁸⁹ have proven instrumental. They would be more effective compared to ordinary calls because they would ensure industries working together across sectors and value chains, based on predefined targets. This is a pre-requisite for achieving, for instance, circular economy goals, where cross-sectoral cooperation along and across value-chain cooperation is vital. following areas for future partnerships with a lead under this cluster have been identified:

- **Made in Europe**
- **Key Digital Technologies** (institutional)
- **Photonics**
- **Artificial Intelligence, data and robotics**
- **Smart connectivity – beyond 5 G** (institutional)
- **HPC** (institutional)
- **Circular and Climate-neutral industries**
- **Clean Steel**
- **Metrology** (institutional)
- **Global Competitive Space Systems**

⁸⁹ In the field of digital and industrial technologies, these included 2 institutional, 10 contractual and 1 public-public partnerships; and 3 Knowledge and Innovation Communities

HORIZON EUROPE CLUSTER 5

CLIMATE, ENERGY AND MOBILITY

1. Global Challenges and Their Drivers

The main objectives of this cluster are to fight climate change, improve the competitiveness of the energy and transport industry as well as the quality of the services that these sectors bring to society. This requires to better understand climate change's causes, evolution, risks, impacts and opportunities, and to make the energy and mobility systems climate- and environment-friendly, smarter, safer, more resilient, inclusive, competitive and efficient (minimising possible rebound effects). The overarching drivers are the need to decarbonise the energy and transport sector by 2050, while, at the same time, boosting their competitiveness – taking into account that both sectors represent an important share of GDP and jobs in Europe, that the transformation of these sectors offers tremendous business opportunities on a global scale, and that the services of both sectors represent major cost factors for businesses and households alike and are indispensable for the well-being and quality of life of citizens and the competitiveness of the European economy as a whole. Actions will therefore support directly EU policy priorities in the areas of climate, energy, and transport, and contribute to creating more and better jobs, accelerating industrial transformation and generating innovation-based and inclusive growth.

Energy and transport sectors are vital for the European economy, for the mobility of people and goods and for affordable and sustainable energy supply for European citizens. Both sectors are the lifeblood of an integrated European single market, territorial cohesion and an open and inclusive society. At the same time, energy- and transport related activities cause the largest part of greenhouse gas emissions in the EU – the energy sector representing 54 %, the transport sector 24 % of EU greenhouse gas emissions in 2016⁹⁰. As evidenced by the long-term strategy, digitalisation and decarbonisation will transform both sectors in the coming decades, and they will be increasingly intertwined. At the same time, becoming a leading actor on fast expanding global markets for sustainable technologies and services is imperative for the European economy, and the energy and transport sectors in particular.

2. EU Policy Objectives

The EU has been at the forefront when addressing the causes and challenges of climate change and strengthening a concerted global response in the framework of the Paris Agreement. In this context, the European Commission presented in November 2018 its vision⁹¹ for achieving net-zero greenhouse gas emissions by 2050. The long-term strategy outlines a vision of the technological, economic and societal transformations required to achieve climate neutrality, and ensuring a socially fair transition that does not leave any EU citizens or regions behind.

R&I will determine the speed at which this transition can take place, directly affecting the associated costs, impacts and co-benefits, such as better air quality, increased employment,

⁹⁰ <https://ec.europa.eu/eurostat/statistics-explained/pdfscache/1180.pdf>

⁹¹ COM(2018) 773 final, A Clean Planet for all

social inclusion, sustainable resource management, and reduced dependency on fossil fuels. The key to success is to develop a wide portfolio of cost-effective and efficient carbon-free alternatives for each GHG-emitting activity, often in combination with enhanced sector coupling, digitalisation and system integration. The rate at which European R&I actions succeed in developing, upscaling, implementing, and commercialising such innovative solutions will steer EU's future competitiveness of its existing and newly emerging industries.

In the medium term, the Energy Union Strategy provides the regulatory framework for achieving the EU's 2030 greenhouse gas emission reduction target – a decrease by 40% compared to 1990 levels⁹² – in a cost-efficient way, including the EU Emission Trading Scheme, EU legislation and national targets. Sectoral EU legislation, such as the Clean Energy for All package and the Clean Mobility packages, imply major market transformation by 2030 in the energy and transport sectors. Horizon Europe can make a major contribution to bring more low and zero carbon technologies to market readiness and feed the innovation cycle with discoveries that may lead to disruptive solutions in the longer term.

Coordination of EU instruments with private sector engagements and funding programmes within Member States is essential to accelerate transformation and maximise impact. In the energy area, the Strategic Energy Technology Plan (SET-Plan) helps align research and innovation between the private sector, the Commission and Member States. Similar guidance for the transport sector is provided by the Strategic Transport R&I Agenda (STRIA). As regards climate knowledge, JPI Climate provides a platform to align national research priorities according to a jointly agreed Strategic Research and Innovation Agenda (SRIA).

Activities in this cluster will contribute to multiple Sustainable Development Goals, with the most direct impact on SDG 7 (Affordable and clean energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action). In addition, SDG 3 (Good health and well-being), SDG 6 (Clean Water and Sanitation), SDG 8 (Decent work and economic growth), and SDG 12 (Responsible production and consumption) will be positively impacted.

3. Expected Impacts

The desired impacts are further specified in the following section in relation to each priority.

4. Key R&I Orientations

The energy and mobility sectors are closely interlinked and face many common challenges. An integrated approach is needed to maximise synergies and cross-fertilisation across these sectors. For example, research and innovation actions aiming at reducing cost for hydrogen generation and battery capacity – thereby fostering competitive European value chains – would bring pivotal change benefiting the clean energy transition and the decarbonisation of

⁹² Additional targets are set for energy efficiency – an improvement of 32.5% by 2030 – and for renewable energy which should provide for at least 32% of the final EU energy consumption by 2030.

transport at the same time. Similarly, an integrated approach, encompassing energy, mobility (and other sectors), is essential making urban transport and energy systems more efficient and clean thus improving the quality of life in cities and communities. Cross-fertilisation between different industries can also lead to the emergence of new solutions to support the efficient transition to a net-zero greenhouse gas emissions economy.

Figure 1 illustrates the need to not only develop a wide range of advanced low and zero carbon technologies, but to organise R&I activities from a system perspective, by working on solutions (e.g. electrification, storage, zero carbon fuels, carbon neutral communities and cities) across sectors such as energy, transport, infrastructure, and buildings. Infrastructure, network development, digitalisation and skill development of the workforce are key enabling factors for decarbonisation, as well as to enhance security, safety and efficiency of the energy and transport system and the built environment. In addition, climate resilience and climate-proofing of infrastructure help the EU with climate change adaptation and the related socio-economic transformation. Moreover, there is a need to optimise R&I activities from a value chain perspective, to support the circular economy and to reduce environmental footprint and pollution arising from different stages.

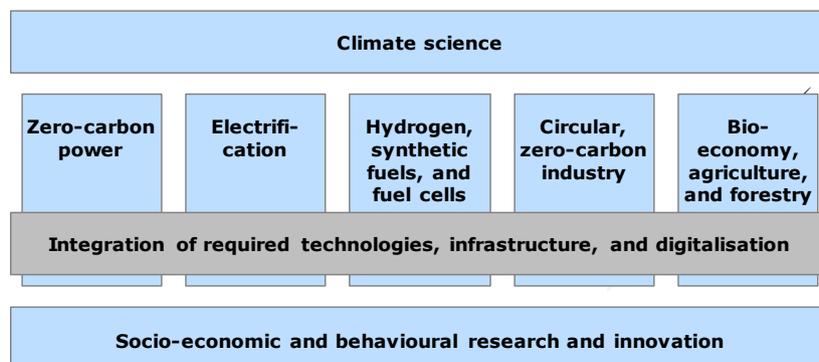


Figure 1: Relevant research and innovation areas for decarbonisation [to be updated]

To address the research and innovation challenges in the context of decarbonising the EU's economy, the Horizon Europe proposal [2018/0225 (COD)] identifies a number of research and innovation priorities within the fields of climate, energy and mobility as follows:

Advance climate science and solutions for a climate neutral and resilient society Challenge: The efficient transition to a resilient net-zero greenhouse gas emissions economy requires profound knowledge in various fields of research. Therefore, advancing climate science and creating a knowledge base that is user centric and can guide the development of policy measures and low- and zero-carbon technologies are essential to catalyse this transition. User guidance is important not only to support the mitigation of climate change but also to be prepared to adapt to its future and already felt impacts. Europe has been at the forefront of climate science and has to continue to deliver the knowledge to enable efficient decarbonisation pathways. Therefore, addressing this challenge will involve for example advancing efforts of the climate science community to perform research that furthers our knowledge, closes knowledge gaps (e.g. IPCC reports), developing the tools that support decision makers, and evaluating the societal impact of climate change and the technologies required for a low-carbon transition.

Expected impact: Impact will be generated along three main research and innovation objectives. The first objective is to accelerate climate action (both mitigation and adaptation) uptake globally in line with the Paris Agreement and the SDGs, by improving knowledge of the climate-earth system and by proposing and evaluating solutions for short-to-medium and long-term systemic impact. The second objective is to contribute substantially to key international assessments such as the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). The third objective is to strengthen the European research area on climate change.

Potential research challenges and topics⁹³:

- Build a user-driven knowledge base (including state-of-the art climate projections and predictions at appropriate scales) that informs human response to global change;
- Produce actionable science and information management tools to share and engage with stakeholders and inform decision making;
- Design cost-effective net-zero greenhouse gas emission pathways compatible with long-term transitions and the Paris Agreement goals;
- Spearhead the development of climate services and decision-support tools and methodologies to inform adaptation decisions at local, regional, national and global levels, and evaluate adaptive capacities and limits;
- Incorporate and further advance research in social science and humanities, including behavioural science methodologies, integrated assessment modelling, and expertise to assess impacts, opportunities, challenges, incentives and requirements of action in support of a just transition.

Implementation: Potential research challenges and topics will be addressed through collaborative R&I actions, with international cooperation wherever needed. The European High Performance Computing infrastructure can be an enabler for developing the next generation of climate models.

4.2 Cross-sectoral solutions for decarbonisation

The energy and mobility sectors are closely interlinked and face many common challenges. An integrated approach is needed to maximise synergies and cross-fertilisation across these sectors. For example, research and innovation actions aiming at reducing cost for hydrogen generation and battery capacity – thereby fostering competitive European value chains – would bring pivotal change benefiting the clean energy transition and the decarbonisation of transport at the same time. Similarly, an integrated approach, encompassing energy, mobility (and other sectors), is essential making urban transport and energy systems more efficient and clean thus improving the quality of life in cities and communities. Cross-fertilisation between different industries can also lead to the emergence of new solutions to support the efficient transition to a net-zero greenhouse gas emissions economy.

⁹³ For all R&I areas, the planned activities should not be considered as comprehensive nor limitative

4.2.1 Establish a competitive and sustainable European battery value chain

Challenge: Electrification is one key technological pathway to decarbonise substantial parts of demand side sectors. In a world that is increasingly electrified, batteries will become a key technological component. In the road transport sector, affordable, durable, fast-charging batteries with high capacities are an indispensable enabler for large-scale deployment of electric vehicles. In the power sector, batteries can deliver various energy services and enable very high shares of intermittent renewable energy technologies. In short-distance waterborne transport, a switch to battery and hybrid propulsion would enable decarbonisation and a reduction in harmful emissions. There is therefore an urgent need for the EU to invest in the development of an EU battery value chain based on beyond the state-of-the-art technology.

Expected impact: To support the development of a world-class European R&I eco-system on batteries, by advancing the state of the art of battery technology in terms of cost, performance, safety, user convenience, speed charging and environmental (and carbon-) footprint along the value chain, with a view towards establishing a competitive, circular, and sustainable European battery manufacturing value chain.

Potential research challenges: The entire value chain should be covered from materials, electrochemistry, cells to re-use and recycling and cover both for mobile and stationary (e.g. redox flow) applications. Research topics such as innovative materials, advanced cell manufacturing, circular economy and recycling (cluster 4), battery safety and standardisation through pre-normative research should be integrated in this work stream. In terms of TRL levels, both enhancement of close-to-market Li-ion technologies, as well as new promising and longer-term break-through technological solutions⁹⁴ should be included.

Implementation: In order to develop a coherent, cross-cluster (e.g. for materials, manufacturing) and strategic battery research programme, and enhance leverage and industrialisation of research results, it is proposed that this strategic R&I area is developed through a co-programmed partnership with industrial players and the research community. International cooperation is key to improving the worldwide sustainability of the entire batteries value chain.

4.2.2 Strengthen the European value chain for low-carbon hydrogen and fuel cells

Challenge: Near zero carbon hydrogen and fuel cell technologies offer a major decarbonisation pathway for energy, transport and industry. Hydrogen offers significant potential for large-scale, long-term storage of renewable energy. There is a growing interest to use hydrogen in energy- and carbon-intensive industry, in particular the steel industry, for the direct reduction of iron ore in steelmaking, and in the chemicals sector as an important chemical feedstock. Hydrogen has started to be used as an energy carrier in the transport sector, in logistics and in the heating sector. In order to achieve large-scale deployment, major advances are needed to be achieved in terms of cost, performance and convenience for the supply, infrastructure and demand side technologies.

Expected impact: Advancing the state of the art in terms of cost, performance, safety and environmental (and carbon) footprint will allow to the global leadership role of European industry along a competitive near-zero carbon hydrogen supply chain.

⁹⁴ R&I envisaged under the FET initiative on future battery technologies will be integrated in the partnership

Potential research challenges:

- Near-zero carbon hydrogen production pathways (including using new materials), particularly renewable based and including energy system integration aspects.
- Development of infrastructure for safe and cost-efficient transport and storage of hydrogen and hydrogen-rich energy carriers, incl. long-term, large-scale storage of hydrogen as energy buffer.
- Demand side technologies (including fuel cells) to produce power and/or heat for mobile and stationary applications. In the transport sector, focus on long range, heavy-duty road freight, rail, and water-borne⁹⁵.
- Life-cycle analysis for the design of hydrogen supply chains.

Implementation: Building on the existing Joint Undertaking, it is proposed that this strategic R&I area is implemented through an institutionalised partnership with strengthened industrial participation combining public and private financial resources across the value chain, to develop a coordinated pan-European approach. International cooperation will be established in particular through the Mission Innovation Challenge on Renewable and Clean Hydrogen. Synergies will be sought with the cluster 'Digital, Industry and Space' and cluster 'Food and Natural Resources'.

4.2.3 Develop sustainable infrastructure, services and systems for smart and sustainable communities and cities

Challenge: With more than 80% of the EU's population living in urban areas it is essential to adopt new system approaches to (re)design our spaces/cities, incorporating regenerative paradigms with a focus on new energy & mobility systems with integrated mass transit, supported through user-friendly and secure digital services. Co-design and co-creation approaches with- and for society can help ensure uptake and deployment of solutions.

Expected impact: Increase the overall energy and resource efficiency as well as the climate-resilience of Europe's cities and communities and their attractiveness to businesses and citizens in a holistic fashion (including business models, financing issues, incentive structures and social innovation) by targeting mainly infrastructure (including green infrastructure), mobility services and energy systems. Improve air quality, resilience of energy supply, intelligent mobility services and logistics, comfortable and affordable housing.

Potential research challenges:

- City/district energy systems and mobility towards the EU-wide deployment of low-carbon, Positive Energy Districts, Energy Communities and zero-emission mobility and logistics by 2050;
- Quality of life for the citizens through demand-based, accessible and safe mobility and logistics, urban social innovation, cities' and communities circular and regenerative capacity,

⁹⁵ Hydrogen applications in aviation will be addressed separately in R&I related to aviation

- Nature-based solutions and circular material, reduced life-cycle environmental footprint and pollution in cities;
- Next generation scalable interoperable digital infrastructure and software solutions for innovative services across different urban sectors (energy, mobility, water, urban planning, etc.), fuelled by latest ICT (Artificial Intelligence, Internet of Things, new computing paradigms, etc.) and (open) data governance models (including new business models). Robust and effective financing solutions and business models to increase investors' confidence.

Implementation: Potential research challenges and topics will be addressed through collaborative R&I actions, and/or as part of a potential cross-cluster Horizon Europe Mission in the area of 'Climate-Neutral and Smart Cities'. There is added value in bringing together EC-funded projects with large stakeholder platforms and the co-programmed partnership "Built environment and construction".

4.2.4 Foster emerging breakthrough technologies and climate solutions

Challenge: Although the contribution of a wide range of technologies to decarbonisation is already foreseeable, EU R&I programming should also leave room for unanticipated emerging and break-through technologies with a high potential for decarbonisation. Research in this area can be technological in nature but needs to be accompanied with assessment of environmental impact, social and economic impacts, and possible regulatory needs. Examples of such cases can be in the areas of: direct conversion of solar energy and artificial photosynthesis; direct air CO₂/methane capture and storage (DACCS); methane cracking; sustainable production of synthetic fuels from renewable energy; disruptive transport technologies, etc.

Expected impact: The emergence of unanticipated and/or the sufficient development of emerging zero-greenhouse gas and negative emission technologies, including, in parallel, the assessment of their technological and economic potential, as well as their environmental impact, social acceptance and possible regulatory needs.

Implementation: This R&I priority will be implemented through a mix of non-prescriptive and open approaches, in order not to exclude relevant future frontier technologies and keep flexibility and more targeted support to highly promising emerging technologies at an early stage of development. Topics in this area should preferably be implemented through strong international collaboration, for instance Mission Innovation.

4.3 Develop cost-efficient, net zero-greenhouse gas energy system centred on renewables

The transition of the energy system will rely on reducing the overall energy demand and decarbonising the energy supply side. R&I actions will contribute to make the energy supply side cleaner, more secure and competitive, notably by boosting cost performance and reliability of a broad portfolio of renewable energy solutions and by making the energy grid more flexible so it can accommodate higher shares of renewable energy in a secure and flexible way. Innovative energy storage solutions can play an important role in this respect. To reduce CO₂ emissions from the power and energy-intensive industry sector, solutions for capturing, utilisation and storage of CO₂ (CCUS) will be matured. To accelerate technological progress along the value chain and maximise EU added value, EU support should be developed and implemented in synergy with national initiatives, leveraging actions

in support of the priorities and targets set by the EU's Strategic Energy Technologies Plan (SET-Plan).

4.3.1 Achieve global leadership in renewable energy

Challenge: The EU long-term climate strategy highlights the pivotal role of renewable energies in the future energy system and the achievement of the zero-emission target. Renewables provide also major opportunities for the decarbonisation of other sectors such as heating/cooling, transportation and industry and their large scale and decentralised deployment will also improve security of energy supply and boost domestic jobs. While efficiency improvements for the more established renewables, such as wind energy, photovoltaics or bioenergy, are envisaged, a further diversification of the technological portfolio is also needed to support the clean energy transition. Renewable fuels, including synthetic and biofuels provide long-term solutions for the transport sectors, in particular for applications where fuels with high energy density are required, while at the same time help reducing the carbon footprint of these sectors in the long-term.

Expected impact: To foster European global leadership in affordable, secure and sustainable renewable energy technologies and services by improving their competitiveness in global value chains and their position in growth markets, notably through the diversification of the renewable services and technology portfolio. To provide sustainable solutions for specific transport needs in aviation, shipping, or heavy duty road transport, for the heating/cooling sector, and in the heavy industry, within an overall circular economy concept in synergy with the bioeconomy.

Potential research challenges:

- Develop disruptive renewable energy and fuel technologies and systems, including the use of new materials, for existing and new applications and breakthrough solutions;
- Improve efficiency, competitiveness, sustainability of renewable energy and fuel technologies and their value chains (from cradle to recycling and final grave) to allow their scaling up in market and market penetration, thus securing energy independence;
- Develop flexible renewable-based solutions and fuels allowing high penetration in the energy system;
- Significantly expand renewable solutions and fuels in sectors other than power generation;
- Develop solutions to integrate renewables efficiently within the existing energy system infrastructure;
- Create synergies of bioenergy with bio-economy and other industrial sectors, in particular for new sustainable feedstock development and through the development of integrated bio-refineries.

Implementation: Potential research challenges and topics will be addressed through collaborative R&I actions. Actions on biofuels will need to be coordinated cross-cluster with activities of cluster 'Food and Natural Resources'. International cooperation with other technology leaders will be pursued where relevant (in particular through the Mission Innovation initiative).

4.3.2 Develop flexible, zero greenhouse gas emission and citizen-centred energy systems and grids

Challenge: Decarbonisation, cost-effectiveness and affordability, security and stability of supply and other objectives of the clean energy transformation depend on an efficient and effective network management and optimisation, leading to increased demand response and the ability to integrate increasing shares of variable renewable energy. Exploiting synergies between different electricity, heating and cooling networks, gas networks, transport infrastructure and telecom networks will be crucial for enabling the smart, integrated and flexible operation of the relevant infrastructures.

Expected impact: New approaches to manage smart and cyber-secure energy grids and related investments to enable more interaction and optimisation between producers, consumers, networks, infrastructures and vectors ensuring the cost-effective uninterrupted and affordable supply of energy to households and industries in a scenario of high penetration of variable renewables and other new low carbon energy supply.

Potential research challenges:

- Technologies and tools, including the use of Internet of Things and Artificial Intelligence, for electricity networks to integrate renewables and new loads, including flexibility solutions for managing electricity grids and Pan-European energy network management approaches, including improved cross-border cooperation in the transmission grid;
- New approaches and tools to empower market players, consumers and communities (beyond smart meters);
- Solutions for the integration of energy systems and coupling of different energy vectors, networks and infrastructures, in the context of a digitalised and cyber-secure energy system, relying also on EU-specific technologies (e.g. encrypted Galileo services);
- Develop/demonstrate techniques to use gas infrastructure to transport low-carbon gases, including hydrogen;
- Integrated local energy systems, microgrids and modular solutions;
- Innovative grid services through demand response, storage and small-scale production of energy from renewable sources.

Implementation: Potential research challenges and topics will be addressed through collaborative R&I actions. Leveraging more investments and a better coordination with national funding programmes may require a partnership approach.

4.3.3 Develop carbon capture, utilisation and storage (CCUS) solutions for the power sector and energy-intensive industries

Challenge: Carbon Capture, Utilisation and Storage is a major CO₂ emission abatement that holds great potential for the power sector and especially for industries with high process emissions such as cement and steel. It is also an indispensable technology to allow the production of large volumes of zero-carbon ('blue') hydrogen from natural gas to kick-start the decarbonisation of sectors such as steel or refineries, until sufficient renewable ('green') hydrogen becomes available.

Expected impact: To accelerate the development of CCUS as a CO₂ emission mitigation option in electricity generation and industry applications. This includes CCS in combination

with bioenergy (BECCS), resulting in 'negative' CO₂ emissions. It can also address the conversion of CO₂ to products either to replace the use of fossil fuel feedstock (i.e. production of synthetic fuels) or to store it for a climate-relevant time horizon (e.g. mineralisation), in collaboration with cluster 'Digital, Industry and Space'.

Potential research challenges:

- Development and demonstration of novel energy efficient, cost-effective and environmentally friendly capture technologies, including using new materials;
- Development of new storage sites (including operational best practices and public engagement);
- Feasibility studies for the development of CC(U)S hubs and clusters;
- Improving the CO₂ balance and energy performance of CO₂ conversion to value-added products.

Implementation: Potential research challenges and topics will be addressed through collaborative R&I actions, in particular with cluster 'Digital, Industry and Space' which includes industrial CCUS applications in the co-programmed partnership 'zero-carbon and circular industries'. International cooperation will be pursued both with other technology leaders (in particular through the Mission Innovation Carbon Capture Challenge) and with carbon-intensive technology followers to enhance the EU energy and climate diplomacy.

4.3.4 Develop flexible and efficient energy storage solutions

Challenge: Capturing excess electricity and heat to use it at a later point in time is an essential requirement for the cost-effective and secure transition of the energy system. Chemical, mechanical, electrical and thermal storage solutions will increase the flexibility of the energy system and complement the research and innovation areas of batteries (area 2.2.1) and hydrogen (area 2.2.2).⁹⁶ More than 50% of our energy use is thermal energy. Therefore, thermal energy storage enables a higher utilization of variable renewable sources in the heating and cooling sector.

Expected impact: Advancing the technological readiness of centralised and decentralised energy storage for industrial-scale and domestic applications.

Potential research challenges: For energy storage, the research priority is to work on new, low-cost solutions (including the use of new materials) enabling to widen the scope and scale of application of storage technology. There is a particular need to:

- Develop more compact thermal energy storage for domestic applications of storage periods typically up to 4 weeks long;
- Re-design large-scale thermal energy storage for district heating and cooling in order to match the seasonal supply and demand of a large number of renewable sources on a district level;

- Develop more efficient electrical storage solutions (such as supercapacitors and superconducting magnetic energy storage);
- Develop novel mechanical storage technologies;
- Demonstrate the integration of different energy storage solutions in the grid;

Implementation: Potential research challenges and topics will be addressed via collaborative R&I. Actions will be developed in complementarity with other areas addressed in this cluster.

4.3.5 Leverage more public and private investments in clean energy systems

Challenge: All pathways to reach the clean energy transition require a better leveraging of public and private investments. Over the last decade, Strategic Energy Technology Plan (SET Plan) built platforms to align R&I agendas in dedicated areas stimulating Member States to coordinate national programmes and to pool funding across borders. Given the scale of the R&I investments needed, this leverage effect on public and private funding towards joint R&I activities in support of the clean energy transition should be intensified. The proposed co-funded partnership would deepen the trans-national integration in thematic areas of joint interest, such as connected energy systems or wind energy.

Expected impact: Leverage public and private funding towards joint R&I activities and necessary accompanying measures in support of the clean energy transition, and coordinate national and regional research programmes with the aim to create trans-national integration in thematic areas of joint interest within the European Research Area.

Implementation: The proposed co-funded partnership would build on the work already carried out in the SET-Plan – i.e. definition of common targets and creation of Implementation Plans endorsed by Member States – and leverage public and private funding towards joint R&I activities. The proposed co-funded partnership would integrate the existing support into a larger, more efficient and more ambitious system.

4.4 Develop demand side solutions to decarbonise the energy system

Research and innovation actions aiming at fostering demand side solutions and improving energy efficiency are among the most cost effective ways to support decarbonisation, to create inclusive growth and employment in Europe, to bring down costs for consumers, to reduce our import dependency and redirect investments towards smart and sustainable infrastructure. The transition to a decentralised and decarbonised energy system will greatly benefit from the use of smart, digital technologies which will enable buildings and industrial facilities to become inter-active elements in the energy system by optimising energy consumption, distributed generation and storage and vis-à-vis the energy system. They will also trigger new business opportunities and revenue streams for up-graded, innovative energy services which valorise energy savings and flexible consumption. Active consumers will be able to benefit from cost reductions and from a bigger variety of services that contribute to a more comfortable, convenient and healthier living environment.

4.4.1 Empowering citizens to engage in energy markets

Challenge: Citizens are central to the successful development and uptake of low-carbon innovative solutions, from smart energy management and renewable energy generation in their homes to investments in large-scale wind farms. Finding new and better ways to involve

Europe's citizens in the low-carbon transition, in the design / implementation of the policy measures, and for creating win-win situations for consumers and energy producers, network providers and investors is of critical importance. More involved citizens take greater responsibility for their own and the EU's energy security, promote sustainable finance in support of the energy transition and help devise novel and original business models.

Expected impact: Reduce energy consumption and related emissions and increase demand-side flexibility in private households through new business models providing multiple user benefits and contributing to decentralised energy markets. Furthermore, socio-economic research should engage and empower citizens to participate in decision-making facilitating the transition to the energy system necessary to reach the EU's 2050 climate targets.

Potential research challenges:

- Develop technologies, services and business models for enhancing individual decision-making in home life and working life. This implies to move from awareness about the impacts of our consumption habits, lifestyles towards decisions and the adoption of sustainable practices at domestic levels;
- Develop and demonstrate technologies, tools and business models based on multiple (also non-energy) user benefits, for optimising the energy and resource flows within private households;
- Develop and enhance methods of citizen's engagement in long-term energy investment planning and energy transition policies. Develop new participatory models to engage citizens in investments of clean energy projects;
- Socio-economic and interdisciplinary research on re-qualification of workers currently in carbon-intensive sectors and building new employment opportunities targeted towards the needs of the clean energy transition.

Implementation: Potential research challenges and topics will be addressed via collaborative R&I, including citizen-science/user-led innovation approaches. A close cooperation with building and city related R&I initiatives across different parts of Horizon Europe will ensure complementarity. Actions will be closely coordinated with the Clean Energy Transition part of the LIFE programme (2021-2027) which focusses on policy support and market uptake action.

4.4.2 Achieving a highly energy-efficient and decarbonised EU building stock

Challenge: Buildings are pivotal to the energy transition and the achievement of a climate neutral economy. Energy consumption of buildings (in the operation phase) represents approximately 40% of energy consumption and 36% of CO₂ emissions in the EU. Enabling cost-effective energy renovation of buildings is a top R&I objective for the EU which can lead to significant energy savings and better life-cycle resource efficiency. This, together with enhanced interactions of buildings with the energy system and between buildings, opens up a significant decarbonisation and employment potential.

Expected impact: Delivering the technology and socio-economic breakthroughs necessary to achieve the full decarbonisation of the building stock by 2050 through energy efficiency, renewables, digitalisation and smart operation of buildings, also bearing in mind the need to move towards climate neutrality in the longer term and to limit the life-cycle environmental impacts of buildings.

Potential research challenges:

This intervention area will primarily focus on the decarbonisation of buildings and on the contribution of the buildings sector to the clean energy transition, while also taking into account life-cycle perspective and circularity:

- Cost-effective renovation, including design and construction processes, and modernisation of existing buildings towards nearly zero-energy performance level, also taking into account environmental life-cycle performance;
- Digital tools for design, monitoring and optimisation of energy performance of buildings and technical equipment, taking into account life-cycle environmental performance, health, accessibility and comfort criteria, ensuring synergies with relevant policy initiatives (e.g. smart readiness indicator under the Energy Performance of Buildings Directive)
- Cost-effective integration of renewables at building - and neighbourhood - level, energy demand flexibility, integrated heat and electricity storage (including EV charging) and energy symbiosis (e.g. electricity and heat exchanges) with industrial zonings;
- Socio-economic aspects of innovation (e.g. business models, costs & affordability, accessibility, user behaviour and acceptance);
- Life cycle approaches integrating resource efficiency, circular economy and environmental impacts (e.g. biodiversity, natural resource depletion, new materials, carbon footprint).

Implementation: Potential research challenges and topics will be addressed through collaborative R&I actions. Synergies will be sought in particular with cluster 'Digital, Industry and Space' on activities relating to construction, construction materials and circular economy. Furthermore, cooperation with other cluster on life cycle approaches, optimisation of accessibility, safety, comfort, well-being and health in buildings will be essential and addressed in a co-programmed partnership on 'Built environment and construction'.

4.4.3 Support industrial facilities in the energy transition

Challenge: Industry has a key role in the clean energy transition, and also needs to become climate-neutral by 2050 while remaining competitive at global level. This needs to go hand-in-hand with an industrial transformation towards a circular industry. The efficient use of energy and resources will be optimised at all levels: at plant, industrial hub and energy system level. This priority, which focuses on the interfaces of the industrial plants and hubs with the wider energy system, will therefore be implemented jointly with Cluster 'Digital, industry and space' (cluster 4). Industry will switch to renewable and low-carbon energy sources, either produced locally or procured via electricity and gas (including hydrogen) grids. Through flexibility and demand response, industry will also contribute to the stability of energy grids supplied with a growing share of variable renewable sources.

Expected impact: Enable competitiveness and carbon-neutrality of industry through the integration of renewable and low-carbon energy sources and the optimisation of energy flows across integrated industrial installations and the wider energy system.

Potential research challenges:

- Develop and demonstrate technologies, planning and modelling tools and infrastructure for optimising the energy flows (e.g. electricity, heat, Hydrogen) between industrial plants/hubs and the energy grids, so as to enable contribution to the integration of RES, energy efficiency and stability of energy grids;
- Develop and improve technologies to use industrial waste energy (heat, cold ...), including its conversion to other energy vectors, so that it can be re-commercialised in the energy system;

Implementation: Potential research challenges and topics will be addressed via collaborative R&I. To ensure complementarity across different parts of Horizon Europe, these will be addressed through, or in close cooperation with, industry-related R&I initiatives, notably with ‘Climate neutral and circular industries’ in Cluster ‘Digital, industry and space’.

4.5 Develop low-carbon and competitive transport solutions across all modes

Europe is world leader in transport design and manufacturing in all transport modes. The automotive, rail, aeronautics and shipbuilding sectors have a turnover of above EUR 350 billion and employ more than 3.6 million highly-qualified staff⁹⁷. At the same time, transport is a major producer of harmful emissions that contribute to climate change and affect air quality, particularly in urban areas. The transport sector is responsible for 23% of CO₂ emissions and remains dependent on oil for 92% of its energy demand. Furthermore, despite significant technological progress over past decades, projected GHG emissions from transport are not in line with the objectives of the Paris Agreement due to the expected sharp increase in transport demand. Intensified R&I activities are therefore needed, across all transport sectors, in order for the EU to reach its policy goals towards a net-zero greenhouse gas emissions by 2050 and to significantly reduce air pollutants. New technological solutions that will emerge from these efforts will not only contribute to the EU policy goals regarding fighting climate change, but will also enhance the global competitiveness of the European transport sector in all modes. These R&I activities are briefly described below.

4.5.1 Achieve zero-emission road transport

Challenge: The Clean Mobility package and in particular legislation on vehicle emissions implies that low and zero-emission vehicles will gain substantial market shares by 2030. In addition, improving air quality remains a key challenge in many cities and regions throughout Europe. To preserve and enhance Europe’s competitiveness in the automotive sector in this effort, in the face of increasing international competition, and to respond to societal challenges related to mobility, air quality and health, substantial R&I efforts are required focussing on the development of the next generations of zero- and low emission vehicles, including clean road vehicles technologies and technologies of a more systemic nature, which will address the integration of clean vehicles and new system services into the transport system .

⁹⁷ “Towards clean, competitive and connected mobility: the contribution of transport research and Innovation to the Mobility Package” SWD (2017) 223 final

Expected impact: The transformation of road transport to zero-emission mobility through a world-class European R&I and industrial system, ensuring that Europe remains world leader in innovation, production and services in relation to road transport.

Potential research challenges and topics: This priority will address both 1) clean road vehicles technologies (lightweight materials, drive trains, emissions after-treatment systems, power electronics, vehicle management systems and advanced and digital manufacturing technologies) and their infrastructure, including their interfaces, and 2) technologies of a more systemic nature, which will address the integration of clean vehicles and new system services into the transport system. All types of road transport vehicles are included (e.g. two-wheeler, passenger cars, vans, trucks and buses), as well as system integration with infrastructures and services.

Implementation: In order to develop a coherent and strategic R&I programme, and enhance leverage and industrialisation, it is proposed that this strategic R&I area is developed through a co-programmed partnership with industrial players and the research community, building on the existing European Green Vehicle Initiative.

4.5.2 Enhance the competitiveness of rail as a low-carbon mode of transport

Challenge: Pave the way for a major transformation of the railway system: focussing on decarbonisation, automation and digitalization. Moreover, address major issues at EU level, such as congestion, security of energy supply and retain the EU leadership role in producing innovative rail transport solutions.

Expected impact: Achieve the Single European Railway Area as the backbone of an integrated and sustainable mobility in Europe and towards a globally competitive transport system, generating growth and jobs in Europe. Strengthen the EU leadership role in producing innovative rail transport solutions, and their integration into digital service chains.

Implementation: Building on the successful operation of the existing Joint Undertaking, potential research challenges and topics will be addressed via an institutional public private partnership.

4.5.3 Make aviation cleaner and more competitive

Challenge: The European Union is one of the leading exporters of aeronautics products in the world. Aviation is also a growing means of transport and a strong contributor to the European Union economy. Despite technological progress, GHG emissions from aviation are rapidly increasing, both in the EU and globally, making it one of the industry sectors with the highest need for new technological solutions to contribute to meeting the goals of the Paris Agreement. In addition, air pollution and noise levels need to be addressed. R&I is necessary to advance technologies as well as operational procedures of aviation to minimise the adverse environmental effects and maintain the EU's leadership position.

Addressing Aviation's Environmental Credentials

Expected impact: To strengthen European aero-industry collaboration and maintain a global leadership position. To develop innovative, cutting edge projects accelerating the reduction of all aviation impacts and emissions (noise, CO₂ and non-CO₂, manufacturing and end-of-life). Technologies for deep decarbonisation will be developed in the field of aircraft technologies and standards, as well as the use of sustainable alternative fuels. It is envisaged that new technologies will provide for a potential fuel efficiency improvement of [XX%] for next

generation aircraft technology, a potential decrease of [XX%] in aviation non-CO₂ emissions and major progress towards cost-competitive sustainable alternative fuels.

Potential research challenges:

- Better understanding the impact of non-CO₂ emissions, including cirrus contrails, NO_x, SO₂ on climate and environment;
- Reduce all aviation emissions and noise for increased environmental and health protection;
- Apply sustainable low carbon fuels (including synthetic fuels, hydrogen);
- Develop improved fuel efficiency for the next generation of aircraft technology;
- Research new aircraft configurations and new propulsion systems towards substantially enhanced performance;
- Deliver ecological and cost-efficient manufacturing, and end-of-life procedures;
- Promote strategic research activities in non-traditional aviation areas (e.g. electrification, digitalisation, autonomy, data-driven sciences, circular economy);

Implementation: Planned research challenges and topics can be best addressed through a dedicated institutionalised public private partnership, in order to maximise impact and the exploitation of synergies with a more efficient and transparent setup, stronger financial and nonfinancial commitments, potentially complemented through collaborative research projects. At least half of the budget will be allocated to technological solutions aiming at deep decarbonisation.

Air Traffic Management

Expected impact: To overcome current shortcomings of the Air Traffic Management (ATM) systems, while addressing future challenges of digitalised and sustainable aviation. Continuing to develop the Single European Sky - tripling the capacity of the current ATM system, reducing its costs by 50%, increasing safety by a factor of 10, and reducing the environmental impact for each flight by 10%, from a 2004 baseline.

Potential research challenges:

- Develop solutions that address the capacity challenge and deliver safer, greener and more affordable aviation (Modernise and harmonise ATM systems in Europe);
- Address new priorities of the aviation ecosystem (e.g. cybersecurity, urban air-transport, U-space drone traffic management system).
- increased automation of ATM and aircraft, integration of the different systems (aircraft/ATM/airports).

Implementation: Building on the successful operation of the existing Joint Undertaking, planned research challenges and topics can be addressed via an institutionalized public private partnership.

4.5.4 Enable low-carbon, clean and competitive waterborne transport

Challenge: In 2018, a global agreement was reached to cut total GHG emissions from shipping by at least 50% by 2050 compared to 2008, with the ambition of achieving zero emissions⁹⁸. Shipping also contributes significantly to air and water pollution. Automation and information technology is revolutionizing the operations of inland and marine shipping, enabling new business models, increasing efficiency, improving security, developing new markets and supporting competitiveness.

Expected impact: Accelerate the development of low-carbon and clean solution in the shipping sector, improve its system efficiency, enhancing digital solutions and contribute to the competitiveness of the European waterborne sector.

Potential research challenges:

- Increase the performance of hybrid/ full battery electric, fuel cell applications, propulsion systems with low-carbon fuels, on-board renewable energy and improved efficiency through changes in vessel design;
- Automation and digitalisation in maritime;
- R&I in Ports: alternate energy supplies, floating ports, capacity management in context of mega ships, port-city opportunities and integration of water freight and passenger solutions in spatial planning;
- Flexible manufacturing, increasing the competitiveness of production in shipyards, improving attractiveness of inland waterway transport and short sea shipping within integrated supply chains.

Implementation: Potential research challenges and topics will be addressed via collaborative R&I.

4.5.5 Reduce the impact of transport on the environment and human health

Challenge: Transport emissions are one of the main contributors to air quality problems, particularly in urban areas. At the same time, noise also negatively affects health. Electrification promises to address most of these issues, but as some transport modes are more difficult to electrify in the near future, there is need for R&I activities in order to develop appropriate solutions.

Expected impact: Improved scientific knowledge on the impacts of existing and new transport emissions, while at the same time devising ways of reducing emissions and their impacts, by technological or regulatory means, both at the source and once these emissions are in the environment.

Potential research challenges:

- Deeper understanding of the impact of air polluting transport emissions and noise emissions on health and ecosystems;

⁹⁸ Initial IMO Strategy on Reduction of GHG Emissions From Ships
<http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx>

- Develop/demonstrate solutions for the mitigation of these negative effects adapted to each specific aspect;
- Methods to influence environmentally virtuous vehicle end user behaviours and discouraging negative ones (aggressive driving, tampering etc.), taking into account user needs and mobility changing requirements stemming from new forms/future of work.

Implementation: Potential research challenges and topics will be addressed via collaborative R&I, in collaboration with cluster 'Health'.

4.6 Develop seamless, smart, safe and accessible mobility systems

Europe needs to maintain the competitiveness of its transport industry and manage the transformation of supply-based transport to demand-driven, safe and sustainable mobility services. Suitable research and innovation initiatives will help to prepare such transformation. Emerging digital technologies, such as Big Data, Internet of Things (IoT), artificial intelligence, provide a great potential for developing connected and automated transport and managing traffic across the whole transport network. It can enable significant safety, environmental, economic and social benefits by reducing accidents caused by human error, decreasing traffic congestion, reducing energy consumption and emissions of vehicles, increasing efficiency and productivity of transport operations, improving working conditions and creating new jobs. To succeed in this transformation, Europe's ageing transport infrastructure needs to be prepared for enabling cleaner and smarter operations. Research and innovation results will set the basis for future standards, creating European and global markets and adapting and modernising the overall regulatory framework.

4.6.1 Make automated and connected road transport safe and competitive

Challenge: Implement the goals for cooperative, connected and automated mobility on roads at EU and national levels as described in the Communication "On the road to automated mobility: An EU strategy for mobility of the future"⁹⁹ and support the development and deployment of connected and automated, fully accessible mobility technologies, services and infrastructure.

Expected impact: The objective is to bring societal benefits, strengthen the competitiveness of European industry and to manage properly the long transition phase towards a highly connected and automated transport system in a safe and secure way, favouring social inclusion, low emissions and overall efficiency.

Potential research challenges:

- Interaction of automated vehicles with the surrounding environment, physical and digital infrastructure, interfaces with other transport modes;
- Technical enablers and Non-technical enablers: smart sensors, 3D HD maps, advanced satellite navigation/ positioning technologies, data-processing, artificial intelligence and connectivity, ethics, privacy, safety, security, accessibility liability, user and public acceptance, governance and international cooperation;

⁹⁹ COM (2018) 283

- Societal impacts of the automated road transport system (economic, environmental, social, employment).
- Large-scale, cross-border demonstrations to get insights in the abilities of automated driving systems and their limitations and to enable deployment

Implementation: Planned research challenges and topics could be addressed through a dedicated institutionalised public private partnership, in order to maximise impact and the exploitation of synergies with a more efficient and transparent setup, stronger financial and nonfinancial commitments, in collaboration with cluster ‘Digital, Industry and Space’.

4.6.2 Develop efficient and innovative transport infrastructure

Challenge: Infrastructure innovation will be vital for implementing the TEN-T network and, more generally, in implementing the technological transition and efficiently limiting GHG emissions. Thus, there is a need to cater for the need for new solutions to ensure that despite increasing budgetary constraints, EU transport infrastructure can be maintained, upgraded and expanded to ensure competitiveness of the transport system while reducing unwanted impacts.

Expected impact: Develop and validate new solutions to increase efficiency, inter-modality, resistance, safety and security of the transport system, for passengers and freight. At the same time, reduce greenhouse gas emissions from transport operations and improve the environmental performance of transport maintenance and modernisation works, over the entire lifecycle of the infrastructure. The infrastructure will have to withstand more frequent severe weather events by adapting to the climate change.

Potential research challenges:

- Develop and test new methods of transport maintenance and upgrade, with a view to improving safety, climate resilience and environmental impact (incl. habitat) and develop new solutions to accommodate connected mobility;
- Support the development of transport infrastructure which will accommodate new and evolving transport modes and improved integration (national, regional) of transport infrastructure and energy systems through deployment of relevant infrastructure;
- Integration of physical and secure digital infrastructure;
- Develop tools for information and data collection and management to monitor the performance of the infrastructure (asset utilisation rate) and the efficient management of mixed vehicle fleets on road networks;
- Develop and test governance, regulatory, and public procurement models and new contractual performance indicators and incentives to maintain and upgrade infrastructure.

Implementation: Potential research challenges and topics will be addressed via collaborative R&I.

4.6.3 Develop the future transport network and integrated traffic management

Challenge: Lack of timely information, reliability, multimodal coordination, safety/security, passenger comfort and accessibility of collective mobility, exacerbated by inefficient freight traffic all lead to an increased use of individual transport by road. Overcoming system-wide

capacity constraints will allow for better management of traffic streams for passengers and freight, enabling seamless door-to-door mobility and transport, resulting in an optimal traffic mix and circumventing temporary capacity limitations.

Expected impact: Develop and prepare for deployment of an advanced multi-modal network and integrated traffic management system, in order to enable seamless door-to-door mobility, increase safety, reduce congestion and transport related emissions.

Potential research challenges:

- Architecture and concept of operations for an efficient, resilient and adaptable multi-modal network and traffic management (NTM) system, using advanced EU satellite navigation services
- Integration of service chains with cooperative and connected vehicles for improved traffic management and overall higher information percentage rate of mobile travellers.
- Validation of next-generation multi-modal NTM systems (including intra-modal optimisation and development of interfaces)
- Traffic optimisation of conventional, (semi-) automated and unmanned vehicles within a multi-modal NTM system
- Structure and definition of EU-wide co-modal freight transport services within a well synchronised, smart and seamless network supporting global supply chains door-to-door

Implementation: Potential research challenges and topics will be addressed via collaborative R&I.

4.6.4 Enable multimodal freight logistics and passenger mobility services

Challenge: New mobility services are needed to improve opportunities for greater equity and accessibility for people who currently have few options. Public and private transport operators are evolving their service models – blurring traditional demarcations between public transport and private mobility and across modes.

Expected impact: Ensure European competitiveness in logistics and mobility services, while decreasing climate and environmental impact in line with the Paris Agreement. Develop and validate new, low-carbon approaches for the freight transport system and logistics operations over the entire lifecycle. Develop and validate people-centred, sustainable mobility services in all modes in rural and urban areas.

Potential research challenges and topics:

- New digital infrastructures and their interconnectivity and interoperability, to improve the efficiency of logistics chains;
- In the supply chain, the network capacity usage and management as well as synchro-modal services;
- Assess emerging business and operating models, their employment and social effects (e.g. need for upskilling and reskilling of the labour force), considering new digital and space technologies, vehicles (e.g. drones), new mobility patterns, and new global trends;
- Assess the impact and opportunities of cooperative, connected and automated mobility on multimodal freight logistics based on open platforms and standards/ data formats;

- Developing and defining new governance models for accessible, smart mobility services for all;
- Emerging demands through future interoperability of physical, technical, social (health, education, etc.), and spatial systems;
- Adapting the data/IoT eco-system to integrate new technologies from different sources (including non-transport) and to integrate new mobility demand (patterns).

Implementation: Potential research challenges and topics will be addressed via collaborative R&I, in collaboration with cluster ‘Digital, Industry and Space’.

4.6.5 Increase transport safety across all modes

Challenge: Safety is of primary concern for any transport system and the EU set ambitious targets in its 2011 Transport White Paper¹⁰⁰. Research and innovation will underpin the 3 pillars affecting safety - technologies, regulations and human factors (individual and organisational). The approach will be risk-based and systemic, including transport means, infrastructure, the physical environment (e.g. weather) and the various actors (e.g. manufacturers, regulators, operators, users etc.) as well as all their interfaces.

Expected impact: Contribute to drastically reduce accidents and incidents, fatalities and injuries and ensure that the EU is a world leader in safety in all modes of transport by furthering knowledge and awareness, and by developing technologies, products, services, and solutions that reconcile safety with efficiency and user-friendliness.

Potential research challenges and topics:

- Understanding and predictive assessment of safety risks and system effectiveness;
- Accident scenario planning and post-accident response;
- Smooth interaction between all road users, their vehicles and infrastructure in a safe system approach;
- Technologies supporting monitoring and enforcement of current safety regulations, testing/preparation of future standards/rules
- New technologies and safety solutions
- Sharing safety data and knowledge on safety

Implementation: Potential research challenges and topics will be addressed via collaborative R&I.

¹⁰⁰ COM(2011)145

Annex : Overview of links between intervention areas (HE SP) and strategic R&I areas of the Strategic Plan document

X – strong link, o – link (less strong as for 'X')

Intervention areas as in Horizon Europe legal base	Climate Science and Solutions	Energy Supply	Energy Systems and Grids	Buildings and Industrial Facilities in Energy Transition	Communities and Cities	Industrial Competitiveness in transport	Clean Transport and Mobility	Smart Mobility	Energy Storage
Strategic research and Innovation areas									
Develop knowledge and more efficient climate action									
Climate science and solutions	X		o		o		o		
Develop cross-sectoral solutions to decarbonise the energy and mobility sectors									
Batteries		X	X	o	o	o	X		X
Hydrogen		X	o	o		o	o		X
Communities and cities	o	o	X	X	X		o	X	o
Emerging breakthrough technologies and climate solutions	o	X	X	X	X	o	X	o	X
Develop cost-efficient, zero-carbon energy systems									
Renewable energy		X	X	o	X		o		o
Energy Systems and grids		X	X	o	X		X		X
CC(U)S		X		X					
Energy storage		X	X	X	X		o	o	X
Leveraging public and private investments in the Clean Energy Transition		X	X		X				
Develop demand side solutions to decarbonise the energy system									
Empowering citizens		o	X	X	X		o	o	o
Decarbonising building stock		o	X	X	X		o		X

Industrial facilities in energy transition		o	X	X					o
Develop low-carbon and competitive transport solutions across all modes									
Towards zero-emission road transport (2ZERO)			o	o	o	X	X		
Rail			o		o	X		X	
Cleaner and competitive aviation						X	X		
Waterborne transport		o	o		o	X	X	X	
Impact on human health and environment	o				o		X		
Develop seamless, smart, and safe mobility systems									
Mobility and Safety for Automated Road Transport					o			X	
Competitive and innovative transport infrastructure			o	X				X	
Future transport network and integrated traffic management		o	o		o	X		X	
Multimodal freight logistics and passenger mobility services					o	X		X	
Transport safety across modes						X	X	X	

Work in Progress

HORIZON EUROPE CLUSTER 6

FOOD, BIOECONOMY, NATURAL RESOURCES, AGRICULTURE & ENVIRONMENT

1. Global Challenges and Their Drivers

Human activities – driven by rapidly growing global population, unsustainable economic growth, production practices and consumption patterns – are creating mounting pressures on ecosystems (on land and sea) and on natural resources such as soils, water, air and biodiversity. Since 1970, the global demand for natural resources has more than tripled. Without radical changes in the current, linear modes of production and consumption, the demand for natural resources is projected to double between 2015 and 2050^{101,102}.

Natural resources are further degraded in terms of quantity and quality as a result of the impacts of climate change. If current trends continue, global average temperature increase could reach 2°C soon after 2060 and continue to rise afterwards, leading to major adverse impacts on primary production systems¹⁰³, natural systems and societies in rural, coastal and urban areas¹⁰⁴. On the other hand, effective management of land and natural resources whilst safeguarding biodiversity can enhance climate change mitigation and adaptation. Agriculture and forestry have a particular role to play in this respect as these sectors manage 80% of the land in the EU¹⁰⁵.

The continuous, accelerating decline in biodiversity is of particular concern as biodiversity provides the fabric of life with a range of ecosystems services which are crucial for human well-being¹⁰⁶. Main direct drivers of biodiversity loss, in order of their importance, are land use change, overexploitation (through intensive agriculture, forestry and fishing practices), climate change, pollution and invasive species. Underlying causes are production and consumption patterns, human population dynamics, trade, technological innovations, harmful economic incentives and governance¹⁰⁷. Currently, 27% of assessed species in the EU, in particular pollinators¹⁰⁸, and 66% of habitat types are threatened, and the situation may become worse under the business as usual scenario¹⁰⁹; worldwide, about 1 million animal and plant species are now threatened with extinction, more than ever before in human history. At the same time, transformative changes could bend the curve of biodiversity loss, but they are currently not happening quick, up-scaled or integrated enough¹¹⁰.

¹⁰¹ European Commission, Raw Materials Scoreboard 2018

¹⁰² <http://www.resourcepanel.org/reports/global-resources-outlook>

¹⁰³ Primary production systems include agriculture, forestry, aquaculture and fisheries

¹⁰⁴ <https://www.ipcc.ch/sr15/>

¹⁰⁵ https://ec.europa.eu/agriculture/sites/agriculture/files/cap-indicators/context/2016/c31_en.pdf

¹⁰⁶ <https://www.ipbes.net/assessment-reports/eca>

¹⁰⁷ https://www.ipbes.net/system/tdf/spm_global_unedited_advance.pdf?file=1&type=node&id=35245

¹⁰⁸ EU Pollinators initiative COM/2018/395 final

¹⁰⁹ <https://www.ipbes.net/assessment-reports/eca>; <https://www.ipbes.net/assessment-reports/eca>

¹¹⁰ https://www.ipbes.net/system/tdf/spm_global_unedited_advance.pdf?file=1&type=node&id=35245

All in all, the global ecological footprint of human activities has increased from requiring less than one planet Earth in 1961 to more than 1.7 planet Earths today, and is expected to require two planet Earths around 2030¹¹¹. Already now we are reaching or even crossing “planetary boundaries” of Earth system in a number of areas related to nutrient flows (notably nitrogen and phosphorus) and biosphere integrity¹¹². Accordingly, concerns over environment-related risks for the economy are mounting¹¹³. These concerns are particularly justified for the EU economy, which is largely dependent on fossil resources and many raw materials sourced from international markets¹¹⁴. This when, as matter of fact, the mass-scale use of fossil resources has resulted in anthropogenic climate change, one of the greatest challenge for our societies.

Environmental degradation in conjunction with unsustainable production and consumption patterns pose also serious risks to human health and well-being. Pollution, responsible for 16% of all deaths worldwide, is the largest environmental cause of diseases and premature deaths today¹¹⁵. More than 70% of the diseases caused by pollution are non-communicable diseases (NCDs)¹¹⁶.

Diets inextricably link human health and environmental sustainability. The prevalent unsustainable and unhealthy diets contribute to the global environmental change, and at the same time are the leading risk factor of NCDs and driver of obesity rates. Despite efforts, no EU country has reduced obesity rates in the last several decades¹¹⁷ and at present more than half of the EU’s adult population is overweight or obese¹¹⁸. The transformation to healthy and sustainable diets requires substantial dietary shift from the consumers and a change in the food production^{119,120}. There is a need to make food systems more responsive to the needs and interests of communities, and to empower people with a stronger influence in local food environments.

Moreover, in an ever-changing environment, keeping plants and animals healthy as well as food supply safe are ongoing challenges. Globally, every year pests and diseases cause around 20-40% of crop and animal production losses^{121,122}. Although the food supply in the EU was never so safe as today, the WHO estimates that food-borne bacteria, parasites, toxins and allergens cause about 23 million cases of illnesses and 5 000 deaths in Europe every

¹¹¹ <https://www.footprintnetwork.org/our-work/ecological-footprint/>

¹¹² <https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html>; <https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries-2019.html>

¹¹³ In the last five years, the environmental-risks have dominated in the Global Risk Perception Survey; and in 2019 accounting for three of the top five risks for the economy by likelihood and four by impact. <https://www.weforum.org/reports/the-global-risks-report-2019>

¹¹⁴ <https://ec.europa.eu/eurostat/data/database> <https://ec.europa.eu/eurostat/data/database>

¹¹⁵ <https://www.thelancet.com/commissions/pollution-and-health> <https://www.thelancet.com/commissions/pollution-and-health>

¹¹⁶ [https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736\(17\)32345-0.pdf](https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(17)32345-0.pdf);

[https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736\(17\)32345-0.pdf](https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(17)32345-0.pdf)

¹¹⁷ <https://www.sciencedirect.com/science/article/pii/S0140673614604608>;

<https://www.sciencedirect.com/science/article/pii/S0140673614604608>

¹¹⁸ <http://www.euro.who.int/en/health-topics/noncommunicable-diseases/obesity/data-and-statistics>; <http://www.euro.who.int/en/health-topics/noncommunicable-diseases/obesity/data-and-statistics>

¹¹⁹ <https://euagenda.eu/upload/publications/untitled-74063-ea.pdf>

¹²⁰ <https://www.thelancet.com/commissions/EAT>

¹²¹ <http://www.fao.org/3/a-i6583e.pdf>

¹²² http://www.oie.int/fileadmin/Home/eng/Media_Center/docs/pdf/Key_Documents/ANIMAL-HEALTH-EN-FINAL.pdf

year¹²³ and the European citizen is not fully confident or trusting the food supply systems^{124,125}. Continuous improvement of risk assessment and risk management methods is necessary to make sure that food stays safe at every stage of the food supply systems.

Industrial operations represent about 20 % of the EU's total GHG emissions, of which about half comes from the use of fossil resources as raw material and from industrial processes¹²⁶. The use of biomass and waste for the production of renewable products (e.g. chemicals, materials) and nutrients will strongly contribute to breaking-down the dependence on non-renewable and mineral resources.

While addressing all these challenges comes at a price, the costs of inaction and related societal implications would be much higher¹²⁷. If left unaddressed, climate change and the degradation of natural capital risk to undermine public health and many economic sectors, which depend on the health of natural systems and resources. In this context, agriculture, forestry, aquaculture and fisheries, food industry, bio-based and other related sectors will be particularly affected, thereby jeopardizing food and nutrition security, millions of jobs, economic growth, and overall well-being of people, in the EU and globally.

The concepts of the circular economy, the bioeconomy, the blue economy and the Food 2030 initiative provide an opportunity to balance environmental, social, and economic goals and set human activities on a path to sustainability¹²⁸. In addition to new knowledge, technological, innovation, organisational solutions and industrial transformation, implementation of these concepts requires profound changes in people's choices, lifestyles and behaviours as well as appropriate governance models from the local to the global. A transition to sustainable economic growth and competitiveness can only be successful if it goes hand in hand with increased prosperity and is inclusive. This implies a fair distribution of costs, benefits and risks along the value chains and balanced development of rural, coastal and urban territories in the Member States across the EU and globally.

2. EU Policy Objectives

The EU has the ambition to lead the transition to a low-carbon, climate-neutral, resource-efficient and biodiverse economy in full compliance with the United Nations 2030 Agenda,

¹²³ WHO (2015) Estimates of the global burden of foodborne diseases, p. 255;

https://apps.who.int/iris/bitstream/handle/10665/199350/9789241565165_eng.pdf;jsessionid=8B2AC517A05A7B81BE04E3AF4FC2EAA0?sequence=12355;

https://apps.who.int/iris/bitstream/handle/10665/199350/9789241565165_eng.pdf;jsessionid=8B2AC517A05A7B81BE04E3AF4FC2EAA0?sequence=1

¹²⁴ <https://www.sciencedirect.com/science/article/pii/S0924224418305557>;

<https://www.sciencedirect.com/science/article/pii/S0924224418305557>

¹²⁵ https://ec.europa.eu/info/consultations/public-consultation-transparency-and-sustainability-eu-risk-assessment-food-chain_en;

¹²⁶ Final Report of the High-Level Panel of the European Decarbonisation Pathways Initiative (EC, 2018)

<https://publications.europa.eu/en/publication-detail/-/publication/226dea40-04d3-11e9-adde-01aa75ed71a1>

¹²⁷ <https://hbr.org/2017/06/if-you-think-fighting-climate-change-will-be-expensive-calculate-the-cost-of-letting-it-happen>;

<https://hbr.org/2017/06/if-you-think-fighting-climate-change-will-be-expensive-calculate-the-cost-of-letting-it-happen>

¹²⁸ The transition to a circular economy, including to a circular bioeconomy, is a huge opportunity to create competitive advantages on a sustainable basis. Applying circular economy principles in all sectors and industries will benefit Europe environmentally and socially and in addition have the potential to generate a net economic benefit of EUR 1.8 trillion by 2030(38), result in over 1 million new jobs across the EU by 2030. European Commission COM(2019)22 Reflection Paper "Towards a Sustainable Europe by 2030" https://ec.europa.eu/commission/sites/beta-political/files/rp_sustainable_europe_30-01_en_web.pdf

the Paris Climate Agreement and the Convention on Biological Diversity, as reiterated in recent communications, notably “Clean Planet for All”¹²⁹ and “Towards a Sustainable Europe by 2030”¹³⁰.

Many EU policies and strategies have been developed or reformed to foster the transition to an environmentally, economically and socially balanced future. This includes in particular: EU environmental legislation and policies targeting biodiversity, water, soil and air, the Common Agricultural Policy, the Common Fisheries Policy, the Maritime Policy, EU Arctic Policy, the EU General Food Law, the Circular Economy Package, the Circular Plastics Strategy, the EU Bioeconomy Strategy, the Blue Growth Strategy, the Food 2030 initiative, the new Industrial Strategy Policy and the 2030 Climate and Energy Framework.

Research and innovation (R&I) is crucial to better understand the underlying drivers of the sustainability challenges as well as to devise options and a range of solutions to address them. It needs to be matched with investment in technologies, new business and governance models as well as social and environmental innovation to overcome lock-ins and set humanity on more sustainable pathways. Accordingly, R&I can play a key role in achieving objectives set in relevant EU policies and global commitments. These include: meeting the goals of sustainable development, mitigating and adapting to climate change, guaranteeing the production and consumption of safe and healthy food and bio-based products, promoting sustainable practices in agriculture, aquaculture, fisheries and forestry, ensuring access to clean water, soil and air for all, cleaning up the seas and oceans, preserving and restoring the planet’s vital natural ecosystems and environment.

This is expected to foster an innovative, responsible and competitive European economy generating sustainable jobs and growth.

3. Expected Impacts

R&I in the Cluster 6 aims to advance knowledge, build capacities as well as develop and demonstrate innovative solutions that will accelerate the transition to: a sustainable management and use of natural resources ensuring ecosystem integrity as well as sustainable development and human well-being, including food and nutrition security, in the EU and globally. R&I activities under this Cluster shall create the following interlinked, long-term impacts:

- Reduction of greenhouse gas emissions and successful adaptation of production systems as well as rural, coastal, peri-urban and urban areas to climate change

The climate mitigation and adaptation potential of ecosystems, primary production and food systems will be seized. In particular, GHG neutral and climate-proof production and

¹²⁹ COM(2018) 773 final, A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy; https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf; https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf

¹³⁰ Reflection Paper “Towards a Sustainable Europe by 2030” https://ec.europa.eu/commission/sites/beta-political/files/rp_sustainable_europe_30-01_en_web.pdf; https://ec.europa.eu/commission/sites/beta-political/files/rp_sustainable_europe_30-01_en_web.pdf

consumption will be enabled. Negative GHG emissions through sink and storage functions provided by ecosystems and sustainable bio-based resources, materials and products will be actively enhanced. As a result, European climate targets will be achieved, notably a cut of at least 40% in greenhouse gas emissions (from 1990 levels). In the longer term this will enhance economic, environmental and social resilience.

- Halt of biodiversity decline and restoration of ecosystems
- Biodiversity and ecosystem services in natural systems and in primary production will be better understood, monitored, valued and managed. As a result, the decline of biodiversity, including of pollinators, will be reversed and ecosystem integrity and resilience in land and aquatic environments enhanced. Sustainable management of natural resources; prevention and removal of pollution; attractive jobs, enhanced value creation and competitiveness

The physical and biological planetary boundaries in relation to the use and management of natural resources on land and sea will be better understood and defined. This will provide the basis for a more circular use of resources and the mainstreaming of circular systems. As a result, resource efficiency will be increased and pollution will be reduced all along value chains, from production to consumption and disposal. The resource-efficient management and sustainable use of biological resources will result also in more attractive jobs as well as increased added-value along the whole value chains and their competitiveness. Sustainable management of water resources will help to better cope with the impacts of floods and droughts and reduce the high economic costs related to water pollution control and removal.

- Establishment of primary production and food systems based on sustainability, inclusiveness, health and safety; ensuring food and nutrition security for all

Sustainable, low emission, resilient, competitive and equitable primary production and food systems will become the norm. The potential of aquatic production systems and aquaculture to produce sustainably high quality food and biomass will be unlocked. Imbalances in our food value chains will be corrected, from agriculture and fishing, to the food and drink industry, transportation, distribution, and consumption. Safe use of bio-resources from land and sea will be ensured. Sustainable, safe and healthy diets will be available and accessible for all and a major shift to healthy diets from sustainable food production systems will be achieved.

- Behavioural, socio-economic and demographic change are well understood and drive sustainability, a balanced development of vibrant rural, coastal, peri-urban and urban areas

Citizens, as consumers, as innovators and as entrepreneurs will have knowledge and skills required for and will be actively engaged in sustainable management of natural resources, from production to consumption and disposal. They will have equitable access to information on production, processing and marketing of products and make informed choices. The behavioural barriers will be overcome and healthy and responsible consumption of natural resource will become the norm. Mobilising the forces of digital transformation and socio-economic innovation will facilitate those changes and foster a balanced and interlinked development of rural, coastal, peri-urban and urban areas.

- Establishment of governance models enabling sustainability

Policy design, implementation and monitoring will be supported by strong evidence-based knowledge and tools. Innovation systems will be in place and encourage participatory, place-based innovations which in turn will accelerate the development and adoption of sustainable practices. Solid and reliable information from Environmental Observations will allow better understanding of impacts of global changes and enable sound decision making by public authorities. The EU's and international science-policy interfaces will be strengthened to achieve a global impact on the transition to sustainability.

4. Key R&I Orientations

The present section describes the most important short to medium-term impacts that are expected from R&I orientations under each area of intervention. The short and medium-term impacts of R&I orientations will be key for achieving the long-term impacts outlined in the previous section. As the challenges and impacts under this Cluster are highly interconnected, systems-based approaches will be encouraged. This implies encouragement of interdisciplinary or even transdisciplinary approaches in the R&I orientations.

4.1 Environmental Observations

This R&I orientation will support the Commission and the European Union with Environmental Observation-based information and data in the domains of the global science challenges.

The disruptive technologies emerging in the digital economy offer many opportunities in the field of Environmental Observation to deliver information for EU strategy and policies in bio-economy, food, agriculture, natural resources, and the environment.

The main challenge in this area of intervention is to deliver more reliable and standardised information, building on the FAIR (findability, accessibility, interoperability, and reuse) principle, to better understand the impact of global changes and to feed into sound decision making on the big challenges our society faces (links with all the Clusters and AI's in Cluster 6).

The objectives will be reached through facilitating the sharing and integration of environmental data and information collected from the large array of observing systems contributed by countries and organisations within the Group on Earth Observations (GEO). This includes space-based (Copernicus and other space missions), airborne, in-situ and citizens' observations, e.g. through EU platforms such as the European Open Science Cloud (EOSC), the Copernicus DIAS and the European Marine Observation and Data Network (EMODnet) (links with Cluster 4 (Space) and AI4). The approach will also include developing algorithms, using big data and AI (machine learning) to detect and analyse Earth System relevant information (e.g. in the biosphere), as well as by empowering citizens to contribute to environmental observation and achieve a broader citizens' engagement.

This R&I orientation of work will aim to fill in situ observational gaps and deliver effective solutions for the sustainable use and monitoring of food and natural resources through Environmental Observation, contributing to the Agenda 2030 on sustainable development.

Impacts on the short term consist of better facilitated access to existing ground environmental information through European and global repositories. Furthermore, these efforts will lead to improved time series and geographical coverage of ground environmental observations for e.g. the ocean, Polar regions, and urban and peri-urban areas. It will deliver strengthened

partnerships connecting environmental observation with application development groups in the field of food and natural resources, to provide integration knowledge for decision making and resource management. It should lead to upgraded planetary observation systems integrating European systems and benefiting to European users (links with Cluster 4 (Space)). And this should end up in improved European Big Environmental Observation Data Processing/storage facilities connected to the European Open Science Cloud (EOSC).

This area will support Earth system science activities in relevant domains in the context of climate change and biodiversity, such as the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). This includes monitoring to support the implementation of EU nature, climate and agricultural legislation and the EU biodiversity strategy as well as contributions to the delivery of a more sustainable agriculture under the Common Agricultural Policy (CAP) (links with Cluster 5 and AI2, AI3 and AI5).

This area of intervention will support models and data assimilation for the development of indicators, scenarios, service capacity, and innovation. This will be done for many topical fields including biodiversity, species and ecosystem health, climate mitigation and adaptation (including GHG flux monitoring), food security and food safety, agriculture and forestry, land use and land use change, marine and water conservation and use, urban and peri-urban development, renewable energy and natural resources management. It will furthermore support risk assessment and evidence-based policy for ensuring resilient, secure and safe environment-based systems, including farming. It will look into areas of ecosystem resilience, including tipping points, risk prone areas and disaster risk reduction (links with Cluster 3, Cluster 5 and AI2, AI3, AI4 and AI5).

4.2 Biodiversity and Natural Capital

This R&I orientation will support research, innovation and investment activities to guide the development of new methodologies, technologies and solutions, appropriate policy design, and behavioural and economic change to enable the protection, restoration and sustainable management of ecosystems and natural capital.

Biodiversity and natural capital are essential for mitigating and adapting to climate change. To enhance this potential, inter-relations between biodiversity, ecosystem services and climate change mitigation and adaptation, including carbon sequestration dynamics from land and sea, must be better understood (in collaboration with IA4). EU R&I will contribute to accelerate the uptake of ecosystem-based approaches and nature-based solutions to climate mitigation and adaptation, to restore fully functional ecosystems so that they can play their role as carbon sinks contributing to the aims of the Paris Agreement, and explore complementary action in digital, regulatory framework and standards, market, investment, insurance, behavioural and socio-economic areas.

A better understanding of biodiversity and ecosystem services, and impacts of their decline, will mobilise capacities and investments for their conservation, restoration and sustainable management, also through in-situ research across ecosystem types, and thus facilitate the continued provision of all ecosystem services, which underpin our economy and society.

This includes addressing the drivers of biodiversity loss and their interactions – land use change, overexploitation (through intensive agriculture, forestry and fishing practices), climate change, pollution and invasive species, and their underlying causes (production and consumption patterns, human population dynamics, trade, technological innovations, harmful

economic incentives and governance) – their temporal, sectoral and spatial effects, the development of solutions to mitigate their impacts and the promotion of practices that enhance biodiversity (together with IA3 and 4). Essential tools that will be developed and improved are projections/forecasts, integrated models, scenarios and pathways that integrate socio-economic value, behavioural and bio-physical factors for biodiversity conservation and restoration, including tipping points and planetary boundaries.

Assessing and valuing biodiversity, ecosystem services and nature-based solutions, and supporting the development and adoption of natural capital accounting frameworks and metrics will ensure their mainstreaming in public and private decision-making. A necessary pre-condition for efficient biodiversity action is investment into long-term integrated monitoring frameworks and associated tools, including new technologies and approaches (together with IA1), to monitor trends and dynamics of drivers of change and of biodiversity and ecosystem services.

The crash of insect populations calls for a better understanding of its causes and to look for solutions to mitigate its effects on ecosystem functioning and their impact on citizens' life. EU R&I will in particular focus on the role of pollinators in the integrity of ecosystems and the availability of their services, which should help to prioritise and better integrate pollinators into habitat conservation plans and strategies, as called by the EU Pollinators initiative (together with IA3).

Better understanding of the links between pollutants and human health, well-being and ecosystems are needed to develop systemic approaches tackling them (with IA3, IA4, IA5 and Cluster 1). Innovative nature-based solutions will be developed and tested to reduce pollution and revitalise degraded ecosystems and reverse biodiversity decline, notably man-made ones as well as human health. There are still significant gaps in the knowledge of environmental behaviour and eco-toxicological features of chemical compounds and mixtures. Their characterisation could be related to questions on human toxicology and exposure (Cluster 1).

Assessing how extraction, production, consumption, trade, and behaviour patterns, especially primary production and food systems, affect biodiversity loss, and how ecological transitions can be socially fair is a priority. Better understanding on how measuring and valuing natural capital changes the public and private decision making at all levels is needed, including for business and investors, and for exploring solutions to improve the biodiversity impact of retailers in global value chains. Impacts of digital transformation, new emerging technologies and social innovation on biodiversity need to be addressed. This includes maintaining materials in the economy for as long as possible and comprehensive assessment methodologies for nature-based solutions in business and for social justice (performance indicators, standards, reference models, risk analysis, life cycle assessment). A robust science and evidence base will in turn contribute to EU coordinated action on the sustainable finance action plan, so as to shift investment towards more biodiversity-friendly activities.

Development of innovative governance models, participatory approaches and integrated decision-support tools are expected to enable systemic approaches and a swift implementation of policy actions for meeting sustainability, biodiversity and climate challenges set towards 2030. Successful transition to sustainability requires an agreement in the communities on the preferred options for development beyond the identification of feasible options to address an acute problem. Multi-stakeholder living labs that allow co-

creation of systemic solutions and create space for testing them are innovative governance solutions that implement the ‘innovation principle’ not restricted to biodiversity and natural capital in the strict sense but address transition processes more broadly. Related activities aim at understanding behavioural, socio-economic and demographic change as drivers of sustainability and catalysts for a balanced development of vibrant rural, coastal, peri-urban and urban areas. Science-based tracking mechanisms and methods would enable transparent assessment of their effectiveness. Activities will engage communities of innovators, public authorities, business and public in all parts of the science-policy cycle, including through citizen science, for facilitating co-creation of actions on natural capital and biodiversity.

Another expected impact is the improved science and knowledge base, science-policy mechanisms and tools to support the workings and outcomes of IPBES and IPCC, and multilateral environmental agreements (see international cooperation).

4.3 Agriculture, forestry and rural areas

Sustainable, climate-friendly and resilient farming and forestry systems provide a number of economic, environmental and social benefits. In addition to contributing to food and nutrition security, feeding into dynamic value chains and providing millions of jobs, EU’s farmers and foresters are important stewards of the natural environment and thus have significant potential to mitigate climate change, halt biodiversity loss and provide for healthy ecosystems. EU research and innovation activities in this R&I orientation will advance knowledge, build capacities and develop solutions to use land in more sustainable ways and to move to climate-friendly and resilient agriculture and forestry systems. They will contribute to providing consumers with healthy and nutritious food, developing new value chains and to a balanced development of rural areas, based on implementation of effective, evidence-based policies.

Fostering climate change mitigation, and achieving sustainable management and efficient use of natural resources implies for agriculture striking the right balance between productivity, climate and environmental goals. A proposed, ambitious mission area on "soil health and food" will speed up action for sustainable soil and land management, enhancing the capacity of soils to capture carbon, reducing GHG emissions and buffering the impacts of climate change. The mission will thereby contribute to food and nutrition security in the long-term. R&I activities outside the planned soil mission will equally support solutions for climate- and environmentally-friendly practices, to effectively reduce emissions of major greenhouse gases and the environmental footprint of agricultural activities. R&I will unlock the full potential of LULUCF activities in the mitigation of climate change. New technologies and business models will further enable a “de-fossilisation” of land-based primary production (in cooperation with Cluster 4 and 5, and IA2).

A range of approaches will be developed to enhance resource use efficiency in agriculture and forestry, find alternatives to scarce resources, for example water, and decrease the dependency on critical raw materials (together with Clusters 4 and 5). A better understanding of nutrient flows and a more effective integration of legume crops in farming systems will allow to optimise nutrient management on-farms and across landscapes, thereby also reducing pollution of water, soil and air from primary production. By better linking rural, peri-urban and urban resource flows it will be possible to gain value from residues and by-products, unlock the potential of the circular economy, and hence create attractive jobs, in particular by promoting small-scale, bio-based solutions (in cooperation with IA6) and innovations in farming at the interface between agriculture, aquaculture and forestry.

Agriculture and forestry are severely affected by more variable and extreme weather events and there is an urgent need to foster adaptation of primary production to climate change. R&I outputs will increase the resilience of plants and animals to biotic and abiotic stresses by bringing more diversity into farming and forestry systems and providing farmers with better-adapted crop varieties and animal breeds. R&I will also provide solutions for rural communities to mitigate and adapt to changing climatic conditions, in particular by introducing innovations in the areas of renewable energy, mobility and natural disaster prevention (together with Cluster 3 and 5).

Biodiversity and ecosystem services underpin productivity and resilience of agriculture and forestry; their preservation and restoration at farm, forest and landscape level is therefore essential. Increased knowledge on the benefits of biodiversity-rich and pollinator-friendly practices will serve to develop farming and forestry systems that protect, restore and enhance biodiversity and ecosystem services across a range of scales. The planned partnership “Accelerating farming systems transition: agro-ecology living labs and research infrastructures” will support implementation and upscaling of agro-ecological approaches in primary production, including organic and mixed farming or agroforestry. R&I outputs will improve conservation, management and use of plant and animal genetic resources. Furthermore, results delivered by R&I will allow to better assess the impacts of primary production on biodiversity, identify the ecological boundaries of the bioeconomy and deploy nature-based solutions to enhance biodiversity (in cooperation with Cluster 2).

Health and safety in agriculture and forestry, and of their produce, as well as animal welfare are important societal concerns. Results of R&I under this orientation will enhance capacities to prevent, monitor and control animal and plant pests and diseases including emerging risks. This will result in safe and environmentally friendly methods for plant protection and weed control, thus also enhance the health of workers in agriculture and forestry, of consumers and of ecosystems (in cooperation with Cluster 1). With regard to animal health and welfare, activities will result in a better understanding of environmental and socio-economic drivers of diseases and promote integrated approaches in animal production. The planned partnership “Animal health: fighting infectious diseases” will tackle transboundary animal diseases, antimicrobial resistance and will allow to advance in the implementation of the One-Health concept (in cooperation with Cluster 1).

Knowledge on structure and functioning of food and non-food value chains will support the creation of new value chains, in particular for eco-innovative products based on plant proteins, fruit and vegetables that meet growing consumer demand for healthier and more sustainable diets (in cooperation with IA5 and Cluster 1). R&I results will contribute, in particular, to the development and strengthening of the EU-grown plant protein¹³¹ and organic sectors¹³². They will improve the organisation of value chains and stimulate collaboration among farmers, producer organisations and other actors. This will ultimately lead to greater diversity transparency and competitiveness, more added value and balanced power relations across the whole food and non-food value chains (in cooperation with IA5).

¹³¹ Report from the Commission to the Council and the European Parliament on the development of plant proteins in the European Union (COM(2018) 757 final).

¹³² <https://ec.europa.eu/info/food-farming-fisheries/farming/organic-farming/future-organics>

The socio-economic and demographic changes in rural areas jeopardise the cohesion of the EU territory. Results of R&I will feed into strategies and policies to close the divide between rural and urban areas and benefit vulnerable groups, rural dwellers (in line with Cork 2.0 Declaration) and generational renewal in farming and rural communities (in cooperation with Cluster 2). The development of digital services and skills as part of the digital transformation will enhance connectivity of often remote rural areas and support smart rural communities and businesses (in cooperation with Smart Villages and POSEI, and Cluster 4). This will result in a better understanding of social networks, social capital and social innovation processes and allow for innovations in rural communities which valorise local and regional assets (in synergy with the LEADER programme).

To develop governance models for sustainability, R&I will deliver the necessary data and knowledge base for EU policies addressing agriculture, forestry and rural areas in the period 2021-2027 and beyond. They will deliver foresights and tools for multidisciplinary assessment of sustainability, lock-ins and transition pathways. The acquired data and information will improve monitoring and evaluation of policies, leading amongst others to the creation of observation networks of European forests and harmonisation of data related to forests.

Agricultural knowledge and innovation systems (AKIS) as well as social innovation will be key drivers to speed up the take-up of results. This will include promoting place-based innovations, reinforcing the multi-actor approach and establishing a network of living-labs in agro-ecology.

Due attention will be given to ICT as an enabler, allowing to build an open digital environment and supporting bottom-up innovation in agriculture, forestry, related value chains and rural areas (together with Cluster 4 and IAI). This is in line with the recent declaration of EU Member States on a smart and sustainable digital future for European agriculture and rural areas¹³³.

4.4 Seas, Oceans and Inland Waters

Seas, oceans and inland waters have a central role in climate processes and in the provision of food, biodiversity, critical ecosystem services, renewable energy and other resources. Oceans, seas and inland waters can deliver more food with lower carbon and freshwater footprints than land-based production, while boosting profitability in the sector. Crucially, the ocean economy needs to prepare for and adapt to alterations in the marine ecosystem – notably from climate change and ocean acidification – requiring integrated management frameworks leading towards win-win outcomes for the ocean economy and the ocean environment from Antarctica to the Arctic.

Contributing to the above, science, technology and innovation are key to the development of a sustainable ocean economy, ensuring that by 2030 the potential of oceans, seas and inland waters, their ecosystems and bioeconomies to drive a healthy planet is fully understood, unlocked and harnessed.

¹³³ <https://ec.europa.eu/digital-single-market/en/news/eu-member-states-join-forces-digitalisation-european-agriculture-and-rural-areas>

Designing and deploying an integrated approach (looking at the interlinkages of ocean-climate, ocean-food, ocean-land, ocean-society, renewable energy from marine sources, marine biodiversity, etc.) will lead to systemic solutions that by design respect the health of seas and oceans and planetary boundaries. Knowledge and innovative solutions will support evidence-based policy making and implementation through engagement and dissemination actions and assessment at EU and global level¹³⁴.

Climate change mitigation and adaptation will be enhanced through the improved scientific knowledge and innovations that will allow to better understand, forecast, monitor the ocean and its changes (including sea level), the climate-ocean interface and the impact of stressors and global changes on ecosystems and maritime sectors¹³⁵. The development and demonstration of Greenhouse gas "neutral" and climate-proof production and exploitation innovations will contribute to climate neutrality and support the adaptation of fisheries, aquaculture and sustainable exploitation of ecosystem services and other resources in the context of climate change and other global changes (in cooperation with Cluster 3).

Preservation and restoration of biodiversity and ecosystem services will benefit from increased understanding of marine biodiversity and other biological resources, marine ecosystems, planetary boundaries and ecosystem services at sea and in coastal areas¹³⁶ (together with IA2), including fisheries for the sustainable use and management of natural resources at sea, environmental protection, coastal management, food security and food sovereignty. The development and demonstration of the use of ecosystem-based approaches and other systemic solutions will allow to protect and sustainably use and manage marine biological resources and to enhance ecosystem integrity and resilience in marine and coastal environments.

Sustainable management of natural resources will be achieved through innovative solutions (including circular economy business models and social innovations – together with IA7) to reduce stressors and human induced pressures on freshwater and marine ecosystems and human, algal and animal health, facilitating the development and market uptake of sustainable circular bio-based processes and blue bioeconomy products.

Contributing to global food and nutrition security, will be realised through developed and demonstrated solutions to produce more, safe, healthier and better quality food, and by exploiting new food sources from the seas, oceans and inland waters, whilst conserving biodiversity, thus alleviating pressure on land and fresh water resources and boosting profitability in the sector. This will go hand in hand with sustainable and resilient aquatic food production systems that minimise the use of chemical inputs, nutrients and antimicrobials, and guarantee the transparency and traceability of aquatic food products (together with IA5).

¹³⁴ EU policies such as the Common Fisheries Policy, the revised EU Bioeconomy Strategy, the Integrated Maritime Policy (including the Marine Strategy Framework Directive), Maritime Spatial Planning and International Ocean Governance as well as the 2050 Clean Planet vision.

¹³⁵ Investigate the impacts of climate change on marine and coastal ecosystems, examining effects in terms of ocean acidification, sea level rise, temperature and currents changes, extreme events, deoxygenation, eutrophication, abundance of marine resources and food, and other effects on marine sectors;

¹³⁶ This includes research needs from the ongoing negotiations on Biodiversity in Areas Beyond National Jurisdiction (BBNJ)

Establishment of governance models enabling sustainability will benefit from the results of R&I, improving capacities and skills to reap the benefits of digital transformation and socio-economic innovations for more resilient, prosperous, sustainable and dynamic coastal and maritime economies, also by developing management frameworks aligned to policy objectives and ensuring fit for purpose ocean observations¹³⁷ (together with IA1), interconnected with relevant infrastructures, to serve the needs of decision and policy making.

Prevention of pollution and required behavioural and socio-economic changes will be addressed through R&I leading to solutions to limit pollution from maritime infrastructures and transport, energy infrastructures and tourism and by demonstrating adoption of circular economy products to prevent and mitigate littering and polluting. An ambitious mission area is proposed to tackle the health of seas, oceans, coastal and inland waters.

A planned overarching partnership “A climate neutral, sustainable and productive Blue Economy” will cut across several of the above impact areas and it will have a key role in achieving the desired impact on a sustainable Blue Economy in Europe through a jointly supported R&I programme in the European Seas.

4.5 Food Systems

The global food system is facing a range of challenges, including the triple burden of malnutrition (undernutrition, over-nutrition and micronutrient deficiencies), climate change, resource scarcity, biodiversity loss, including in soils, growing and ageing population, urbanization, food waste and food poverty. This requires food systems’ transformation with a shift towards more sustainable and healthy diets aiming to ensure food and nutrition security for all. Food sector is also an important part of the European bioeconomy market in terms of turnover and employment at 50% and 19% respectively¹³⁸. The Food 2030 initiative will support the transition with a systemic approach to make our food system future-proof.

A better understanding of the interactions between the different components of the current food systems will accelerate the transition towards a sustainable, climate-neutral, resource-efficient, trusted and inclusive global food system from land and sea that respects planetary boundaries and delivers safe, healthy and affordable food to all. Innovative solutions and strategies that tackle systemic issues and have high social, environmental and economic impact will play an essential role. R&I will contribute to promoting sustainable and healthy diets; preventing the risks of non-communicable diseases; building the food safety systems of the future; ensuring a more diverse and sustainable protein availability; reducing food waste and rethinking packaging; valorizing the potential of new microbiome knowledge; realizing urban food systems transformation; and building on digital innovations in a coherent food system approach.

To foster climate change mitigation and adaptation, R&I solutions will be developed to improve resource efficiency and circularity, to reduce food waste, rethink packaging and address environmental pressures impacting on the food systems. Results of R&I will provide

¹³⁷ Technologies for the digital ocean (seafloor, water column and water surface) connecting services and communities, and promoted through the Blue Cloud as part of the European Open Science Cloud.

a diverse range of more sustainable and nutritious foods, such as plant based proteins, algae, seafood and insects based proteins, and improve the climate-resilience of food systems. Placed based food innovation will be supported and R&I solutions applied also in urban and rural contexts to ensure the transformation of urban and peri-urban food systems.

The food systems is an important part of the bio-economy, it draws on the services of the same ecosystems whose limits have to be respected. For the preservation of biodiversity and ecosystem services and resources food systems have to create synergies with the bioeconomy, notably for the better use of byproducts and wastes. Sustainability, inclusiveness, safety and health will be embedded in food systems and food and nutrition security ensured. Innovative personalized nutrition solutions will provide a better understanding of needs and predispositions to develop tailored solutions for different targeted groups and in particular for people in vulnerable stage of life to reduce the incidence of diet related and non-communicable diseases (in cooperation with Cluster 1). The potential of the microbiome will open new avenues to improve human health, biodiversity of food resources, sustainability and climate resilience across food systems (in cooperation with Cluster 1 and IA3). Addressing health and nutritional inequalities is crucial to reduce hunger and malnutrition and to support the sustainability transition. Innovative solutions and strategies tackling the causes of food and nutrition insecurity and identifying emergency responses at different levels (cities, regions, etc.) and for different communities (developing countries, vulnerable groups like elderly, migrants, low income groups), will ensure that nutritious, sustainable and safe food is available, accessible, and affordable for all, and at any time (in cooperation with Cluster 1, Cluster 2 and IA3). Challenges to and innovation in the food chain will be addressed by improved risk assessment methodologies and new evidence to support robust food safety regulatory frameworks, including new and emerging food safety risks. R&I will foster solutions for acceptability, trust, transparency, and innovation uptake by citizens. The development of digital innovation will optimize the sustainable use of natural resources along the food system and contribute to foster food safety, crisis management, traceability, transparency and system resilience, to respond to the trend for more personalized, sustainable and healthy food, and to increase EU food industries competitiveness. R&I solutions for food products, services and process will optimize nutritional, structural and functional food properties, food systems sustainability and resources efficiency, reduction and recycling of water, food loss and waste, and the reduction of plastic based food packaging.

Behavioral, socio-economic and demographic changes will be well understood and drive policies. R&I solutions to better understand the factors (such as urban planning, obesogenic environment, cultural and socio economic factors) influencing consumer food choice, their lifestyle and their motivation with a special attention to vulnerable people will facilitate transition towards sustainable and healthy production and consumption. Safe and healthy diets will not only reduce the risk factors of diet-related and non-communicable diseases, but is essential for reaching climate targets¹³⁹ and supports more environmental friendly production systems. European food industries should be involved as they have an essential role to play in facilitating dietary change by providing good quality, safe, affordable and

¹³⁹ COM(2018) 773 final, A Clean Planet for all and SWD: Dietary changes can by 2050 reduce EU GHG emissions equal to 5% of 1990 levels

convenient food with good nutritional (e.g. functional food adapted to different target groups) and sensorial qualities.

Citizen's empowerment and involvement in informal governance systems will be crucial to shift consumer preferences and consumption pattern towards more sustainable and healthy diets. Interfaces between informal and formal governance systems need to be developed and tested to accelerate innovations uptake in society. To develop and establish governance models enabling sustainability, R&I will produce knowledge and innovative solutions to support evidence-based policy-making, implementation and monitoring and to strengthen EU and international science-policy interfaces for improved governance. By addressing political and socio-economic lock-ins starting from the local level of governance, these solutions will ensure policy coherence and societal engagement in developing and applying science-based innovative solutions.

The contribution of the proposed partnership on "Safe and sustainable food systems for people, planet and climate" will cut across several of the above impact areas and will have a key role to support food systems transformation including post-harvest food production and sustainable and healthy diets.

4.6 Bio-based Innovation Systems

Bio-based innovation has a major role to play in the transition to an economy which is climate neutral, circular and operates within planetary boundaries. Building on the use of biological renewable resources, as a substitute for fossil- and mineral-based ones, it fosters climate neutrality in very significant parts of European industrial and economic sectors (e.g. construction, packaging, textiles, chemicals, cosmetics, pharma ingredients and consumer goods). It contributes to achieving the goals of the Circular Economy – for instance through the development of our capacity to turn organic waste into valuable products. At the same time, it capitalises on the enormous advances of biosciences and biotechnology to deliver greener and innovative products, processes and services. The transformative potential of bio-based innovation will also be directed towards economic competitiveness, delivering new value chains, technologies and processes, economic activities and employment, thus revitalising regional economies and local areas.

The contribution of bio-based innovation to fostering climate change mitigation and adaptation strongly relies on the provision of sustainable biomass, grown in a way which respects climate and biodiversity goals and sustains ecosystems integrity, and its conversion into bio-based products and nutrients as a substitute of fossil and mineral-based ones.

R&I will deliver on two main outcomes. First and foremost, it will result in resilience and sustainable biomass production systems for high value bio-based products while ensuring the functions of balanced ecosystems (terrestrial, aquatic) with greater carbon sequestration and biodiversity conservation. A number of ecological approaches can be considered such as multi-cropping strategies, 'agro-forestry', multipurpose biomass, the use of perennials and marginal lands, residues mobilisation and use as well as climate-resilient crops (e.g. drought, pathogen resistant) (in cooperation with IA3). Secondly, it will pursue the establishment of new bio-based value chains through the development of a toolbox of solutions to process diverse biomass into bio-based products, including in advanced sustainable biorefineries, including small-scale decentralised models (in cooperation with IA3). A key approach will be the combination of sustainability and functionality of the developed products. Bio-based products may be suitable for various (longer-term) uses, and new end-of-life requirements

(such as recyclability, compostability), show lower toxicity (e.g. bio-based surfactants, pesticides, insecticides) or present new functionalities (e.g. drugs based on chemical composition or structure) or performances (biodegradability in specific environments) meeting societal needs.

Coupled with its potential to reduce greenhouse gas emissions, bio-based innovation can accelerate the transition from a linear fossil-based economy, which leads to overuse and depletion of natural resources, into a resource efficient and circular bio-based one operating under safe planetary boundaries. R&I will result in solutions to keeping the value of biological resources in the economy for longer through the optimisation of product design, production processes, performance and end-of life, including reuse and recycling patterns. Effective approaches will be devised to the increase of the value generated per unit of biological resources. They could range from the optimisation of the chemical (complex molecules), materials and energy potential of the feedstock to the implementation of the principle of cascading use of biomass. Greater value will also be generated from unavoidable biological wastes and residues, including urban bio-waste and residues from agriculture, food processing, forest sector, fisheries and aquaculture. Also the recovery of nutrients from waste streams to produce bio-based fertilisers will allow for reducing impacts associated to the production and use of synthetic fertilisers. As bio-based products and processing may decrease the presence of hazardous substances, they could improve safety and facilitate circularity. Industrial symbiosis will enable the creation of new value chains and networks where wastes or by-products of an industry or industrial process become the raw materials for another. This includes the capture and use of CO₂ from emissions from bio-based processing into valuable chemicals, materials and products. The flows of biological resources will be better integrated into models of the circular economy, in particular on the circular use of natural resources that account for its ecological boundaries and enhance biodiversity and the delivery of ecosystem services, and metrics and data on the value generated per unit of biological resources will be developed.

With a view to addressing the previous R&I priorities (in cooperation with IAs 3, 4, 5 and 7), the suitability of the establishment of a potential European partnership in the area of “Sustainable, inclusive and circular bio-based solutions” will be assessed against the compliance of a possible proposal with Horizon Europe selection criteria and expected impact.

Bio-based innovation is not only driven by the need to address pressing societal challenges (such as climate change, resource depletion, biodiversity loss, environmental pollution) but also by the disruptive potential of the unprecedented advances in life sciences and biotechnology. This goes far beyond biomass processing towards allowing the use of nature’s “biological assets”, i.e. its functions and principles. R&I will deliver competitive, sustainable and novel industrial processes, environmental services (e.g. bioremediation for restoring ecosystems, water resources, soil) and consumer products through the application of biotechnologies across bio-based value chains. When coupled with the digital revolution, new tools will be put in place for prospecting, understanding and sustainably using the biological resources (in cooperation with IA 2).

Maximising the impact of bio-based innovation involves the elaboration and establishment of governance models enabling sustainable and inclusive bioeconomy patterns. This key targeted impact cuts across all key R&I priorities identified above. R&I will deliver behavioural and socio-economic change resulting in (i) the revitalisation of local

communities through e.g. new (small-scale) business models and innovative contractual arrangements in value chains, (ii) effective public engagement, mobilisation and mutual learning, trust building and awareness raising, (iii) training and skills development as well as recruitment strategies and education. R&I will result in a deep understanding of multiple boundaries of the bioeconomy. This includes knowledge for evidence-based policy making on (i) bioeconomy impacts, synergies and trade-offs with a healthy environment, enabling their comparison with concurrent and alternative economies (fossil-, CO₂-based), (ii) (international) biomass sustainability criteria and certification schemes, (iii) hierarchy of use of biological and fossil resources (e.g. trade-offs and synergies with food production or other land use). Technological, as well as systemic, territorial, social and environmental innovation will be supported.

4.7 Circular Systems

The recent EC report on the implementation of the Circular Economy Action Plan, the EU Plastics Strategy, the updated EU Bioeconomy Strategy, the reflection paper towards a Sustainable Europe by 2030 and the Clean planet for all strategy acknowledged the need for further progress in scaling up circular economy, reducing pressure on the environment and consolidating the competitive advantage it brings to EU businesses. There is need to: (i) continue supporting research, innovation and investments to develop and demonstrate innovative systemic solutions in various sectors (e.g. plastics, food, textiles, electronics, construction and built environment) and reap their full benefits to cut greenhouse emissions; (ii) address the challenges related to the circular use of natural resources, including recycling, energy and material efficiency; (iii) support new circular business models, and consumption and production patterns; (iv) enhance circularity and sustainable water use and circular nutrient and manure management; (v) develop appropriate indicators and governance systems to measure the progress and accelerate the transition to the circular economy.

Improved knowledge about the potential and the overall environmental impact of circular economy will contribute to reducing GHG emissions along value chains and to fostering mitigation and adaptation to climate change. Investing in systemic solutions for circular economy at regional and local scale (in urban, peri-urban, coastal and rural regions) including new business models, products and services stimulating resource efficiency along the whole value chain, while exploring the potential of digitalisation, will contribute to reducing the environmental footprint of production and consumption, preventing pollution and achieving sustainable management and circular use of natural resources. The development of a holistic view of a working after-use system in particular for plastic based products, incorporating reuse, collection, sorting, mechanical, chemical and organic recycling will also provide insights on how to coordinate strategically the transition towards a circular economy for plastics and other key material flows and support the implementation of relevant EU policies.

Robust approaches to promote active engagement of citizens, to explore the consumer-related aspects of circular economy and identify instruments that can trigger changes in consumer behaviour and make circular economy socially acceptable and inclusive, will be essential to accelerate the transition to circular systems for the sustainable management and use of natural resources. R&I solutions will improve knowledge and develop metrics and indicators for measuring material flows, the circular economy and life cycle performance, governance systems to accelerate expansion of circular economy, including models for multi-stakeholder and cross-value chain collaboration, incentives and financing instruments.

Climate change will require adapting water management to increased scarcity and flooding, as a result of more extreme weather events. Improved knowledge about the status of waterbodies and about long-term change in resources are essential for adaptation. Innovative solutions for the restoration of degraded water bodies and water reuse systems contribute to maintaining natural capital. Transparent water allocation systems to satisfy all needs are essential for sustainable resource use. New governance solutions that build on better spatial planning, based on environmental observation, better modelling and inclusion of citizen and economic actors, like insurances, will be essential to support EU water and climate adaptation related policies.

Cost-effective solutions for mitigation of morphological alterations of water bodies (e.g. barriers, dams, canalisation) and for restoration and management of heavily modified water bodies will help to preserve and restore biodiversity and ecosystems. Innovative solutions, improved analytical tools and monitoring methods to address the negative effects of past chemical stressors and new emerging pollutants (such as micro-pollutants, micro-plastics, pharmaceuticals) will also help improve the chemical status of freshwater and prevent further pollution (in cooperation with IA3).

The ecological consequences of imbalances in the nutrient cycles are visible as eutrophication of surface waters and as contamination of sub-surface waters, with increasing costs for drinking water provisions. Forest areas are also affected and get lost for the production of animal feed. Nutrient emissions cause also impact on air, biodiversity, climate and soil. A comprehensive EU policy to balance nutrient cycles is not yet very well developed. Research and innovation is needed to look at how the EU could move to living within the safe nutrient planetary boundary. Research and innovation activities related to the nutrient cycle shall include inter alia more sustainable sourcing of nutrients for example from wastes, alternative soil management, and livestock emissions and recovery of recycling of nutrients for different industrial sectors. Analysis of emissions from relevant sectors, nutrient budgets, and key actions to be taken to close nutrient cycles across all environmental media will be developed. Innovation activities may develop and test better governance arrangements through stakeholder involvement for the realisation of a nutrient policy on local and regional levels. Actions to develop and demonstrate systemic solutions for a sustainable management of nutrients flow in Europe will enhance sustainable, inclusive, safe and healthy primary production and food systems.

It is expected that part of the above activities could be implemented in the context of the mission areas “Healthy Oceans, Seas, Coastal and Inland Waters”, “Soil Health and Food” and “Adaptation to Climate Change, including Societal Transformation” and the proposed partnerships “Circular bio-based Europe: sustainable innovation for new local value from waste and biomass” and “Water4All: Water security for the planet”.

5. European Partnerships

In the area of Cluster 6 the landscape of Horizon 2020 partnerships is characterised by a high share of public – public partnerships. Among those partnerships, two are institutionalised ones (Bio-Based Industries and PRIMA). With a view to rationalise the landscape, the following eight areas for future partnerships have been identified, The specific nature of some of the identified challenges make partnerships a useful means for implementation. This is notably the case if a structured cooperation with already existing broad stakeholder networks is required to create impact from a strategic research and innovation agenda; or if

partnerships with a network of public R&I funding agencies can create synergies. The following areas for partnerships with centre of gravity in this Cluster are proposed:

- Circular bio-based Europe: sustainable innovation for new local value from waste and biomass*, successor to Bio-Based Industries
- Environmental Observations for a sustainable EU agriculture
- Rescuing biodiversity to safeguard life on Earth
- Accelerating farming systems transition: agro-ecology living labs and research infrastructures
- Animal health: fighting infectious diseases
- Safe and sustainable food system for people, planet & climate
- A climate neutral, sustainable and productive Blue Economy
- Water4All: Water security for the planet.

EIT Knowledge and Innovation Communities (KICs). In addition to the support to the abovementioned European Partnerships, the Cluster 6 will collaborate with relevant EIT Knowledge and Innovation Communities (KICs). Thanks to their societal challenge-driven approach and their portfolio of activities, ranging from entrepreneurial education and training, to innovation projects, business creation activities and support services for startups, scaleups and SMEs, the EIT KICs, in particular, EIT Climate-KIC and EIT Food, are well equipped to develop synergies and complementarities with Cluster 6 activities. ‘Water and maritime’ has been proposed a potential theme for a future EIT-KIC and EIT might support in future the KIC in coordinated cross-KIC actions on challenges, like the circular economy, that are so far addresses at the margins of several KICs.

WORK IN PROGRESS

RELEVANT ACTIVITIES IN PILLAR I

Research Infrastructures

Activities on the Research Infrastructures will be aimed at extending the frontiers of knowledge by providing state of the art services to research and innovation communities, thus contributing to the objectives of the clusters and missions supported in Horizon Europe. Identifying the pan-European Research Infrastructures contributing to the clusters and missions in the strategic planning is an acknowledgement of the long-term commitment made by the Member States and the Associated Countries to support these facilities and will avoid duplication of efforts and maximise impact. As these Research Infrastructures will be connected to the European Open Science Cloud (EOSC), the involved researchers will have access to the majority of data generated and collected by Research Infrastructures as well as to HPC and exascale resources deployed under the European Data Infrastructure (EDI).

In the period of reference of the Strategic Plan 2021-2024, the Research Infrastructures activities will support the development of new pan-European Research Infrastructures, such as those identified by the Strategy Forum for Research Infrastructures (ESFRI)¹⁴⁰ and those established under the European Research Infrastructure Consortium (ERIC) regulation¹⁴¹, the integration and opening at European level of research infrastructure services, as well as address issues identified under the Bulgarian and Austrian Presidencies¹⁴² of the Union namely the consolidation of the European landscape of Research Infrastructures and their trans-national access. All fields of science will be targeted including those related to the societal challenges identified in the clusters and missions.

RELEVANT ACTIVITIES IN PILLAR III

RELEVANT ACTIVITIES IN THE 'UNDERPINNING PART'

¹⁴⁰ List available at https://ec.europa.eu/info/files/esfri-roadmap-2018_en

¹⁴¹ EC regulation 723-2009 of 25 June 2009 amended on 2 December 2013 (EU 1261/2013)

¹⁴² Council conclusions of the Competitiveness Council of 29 May 2018 (Accelerating knowledge circulation in the EU) and 22 November 2018 (Governance of the European Research Area)