Orientations

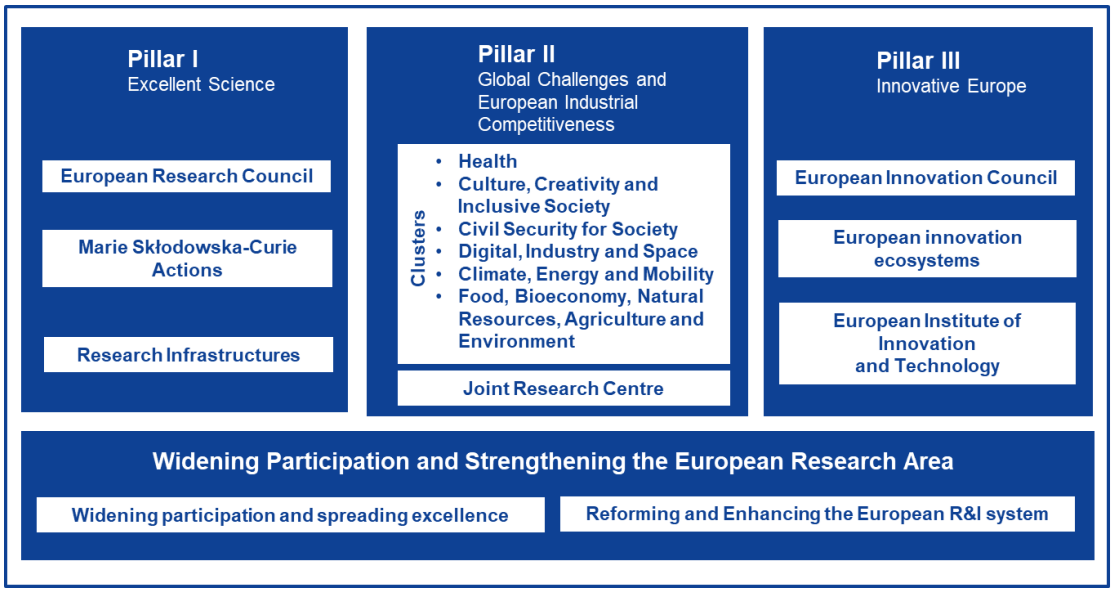
towards the first Strategic Plan for Horizon Europe

Research and Innovation

About Horizon Europe and the Strategic Plan

On 7 June 2018 the proposal for the European Union Framework Programme for Research and Innovation 2021 – 2027 (Horizon Europe) was adopted by the European Commission. In the spring of 2019 the European Parliament and the Council reached a political agreement on key elements of the proposal. According to this agreement, Horizon Europe will be structured in three Pillars, supported by activities aimed at widening participation and strengthening the European Research Area:

Preliminary Horizon Europe Structure



The political agreement – while contingent on the adoption of the long term EU Budget and Horizon Europe legal acts – has allowed the Commission to start the preparations for the implementation of Horizon Europe, including through the first Strategic Planning process.

The Strategic Planning process will focus in particular on Pillar II, "Global Challenges and European Industrial Competitiveness", covering also other relevant activities throughout Horizon Europe. The Strategic Planning process will prepare the Strategic Plan for Horizon Europe for 2021-2024 and facilitate the implementation of Horizon Europe, by setting out **key strategic orientations for the support to research and innovation**. The Strategic Plan will contain a description of impacts to be targeted from 2030 onwards, although in some cases, they might be achieved earlier, cross-cluster issues and intervention areas covered. It will also identify missions and European Partnerships. Overall, the Strategic Plan will describe, within the frame of the legal base, major policy drivers, strategic policy priorities, and the targeted impacts to be supported through Horizon Europe from 2021 to 2024.

About this document

The purpose of this document is to summarise the results of the intense co-design process that took place over the summer and autumn 2019 in view of preparing the first Strategic Plan for Horizon Europe. The views and ideas of more than 7000 respondents were collected through web-based surveys and close to 4000 participants engaged in in-depth debates in the European Research and Innovation Days, which took place in Brussels on 24 - 26 September 2019. The full report on the web-based consultation and on the European Research and Innovation Days can be found online.

This document has been extensively revised to take into account the outcome of the co-design process and the targeted impacts presented in the following pages have been consolidated by exchanges between research and innovation performers, representatives of end-users, interested citizens, relevant organisations, Members of the European Parliament, Member State representatives, and staff of the European Commission.

This document is not the Strategic Plan or its draft, but a solid foundation for the first Strategic Plan and the first Work Programmes of Horizon Europe. The first part outlines challenges that the EU is currently facing and the drivers that are likely to exacerbate them. It then presents the key EU policy objectives and responses to these challenges and outlines the impacts that research and innovation should target to help achieve these objectives.

A section describes specific issues that will be taken into account during the implementation of Horizon Europe, and the future coordination of relevant activities throughout Horizon Europe. Finally, the document presents two novel instruments and approaches for maximising the targeted impacts: the missions and Partnerships in Horizon Europe. The targeted impacts are presented in further detail in six annexes, corresponding to each Horizon Europe Cluster.

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1. Investing in research and innovation – shaping the future we want, together

With a proposed budget of 100 billion euro from 2021–2027, Horizon Europe represents the largest multinational collaborative research and innovation investment in Europe and is open to participants worldwide. The European Union undertakes an investment of this magnitude because research and innovation is 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 is necessary to create new opportunities, tackle climate change, support sustainable economic growth and the competitiveness of our businesses and industries, and to enable better welfare and public services for all Europeans. Research and innovation allows us to shape the future we want for future generations.

While European research and innovation is setting a world standard for excellence, the potential impact of investments in research and innovation is greater when efforts have both a rate and a direction. This view is recognised in the specific objectives of Horizon Europe which highlights the need to *strengthen the impact of research and innovation in developing, supporting and implementing Union policies and … to address global challenges, including climate change and the Sustainable Development Goals*.

Where and how research and innovation funds are invested now is of paramount importance to shape the future we want. That is why a wide spectrum of stakeholders, businesses, public authorities, organisations and interested citizens have been invited to share their views and help help consolidate of the key impacts to be targeted in the first four years of Horizon Europe implementation. Their responses have been overwhelmingly positive: more than 7000 people and organisations gave their views in online co-design surveys and almost 4000 participants discussed Strategic Planning for Horizon Europe at the first European Research and Innovation Days in September 2019. Directing Horizon Europe investments to where it matters most. Shaping the future we want, together.

The United Nations Sustainable Development Goals

2. The challenges we face and the forces that drive them

Our future is shaped by a multitude of factors that evolve and intersect in complex ways. While some events develop rapidly, causing so-called disruptions, other factors evolve more slowly. These **drivers** shape major social, economic, political, environmental and technological transformations as they take root. Since these drivers develop in a relatively stable manner over time, we are able to anticipate with some degree of certainty the challenges to people, planet and prosperity that these forces will create if not appropriately addressed.

One example of such a driver is **demographic change.** As we live longer and populations, especially in Africa and Asia, continue to grow, the global population is expected to reach approximately 8.6 billion in 2030 and 9.8 billion in 2050, while also growing older as a whole. These developments can have a wide range of implications on for example planetary resources, climate change, labour markets, migration, health- and long term care and public spending in general.

As the populations of the eastern and southern parts of the world continue to expand, the centre of gravity in the world economy and global politics will continue to shift in the same direction. In Asia, a growing middle class with rising purchasing power will represent new market opportunities for European businesses but will also add to planetary strain. Africa will contribute the most to a rising population until 2050 and is a continent of opportunities where decentralised, digitally enabled solutions are flourishing. As **new powerhouses in the global economy** take their place on the international scene, established roles are brought into question and in some cases, the multilateral and rules-based world order can no longer be taken for granted. This creates an increasingly complex and volatile environment for Europe, while also challenging the businesses and industries operating internationally.

Another important driver is increased mobility: across borders, and in particular within borders, towards cities. Today, most Europeans already live in cities and more than two thirds of the global population will be living in cities by 2030. While uncontrolled **urbanisation** can lead to a number of challenges related to for instance poor infrastructure, abandoned rural areas and territories, biodiversity loss, inequalities and lower quality of life, urbanisation also represents opportunities as cities can be centres of innovations that gives people better access to education and employment, and even basic goods such as electricity and water.

Finally, **scientific and technological developments**, not the least within digitisation, will continue to transform our society. The process of innovation has been shortened significantly while the amount of disruptive and market-creating innovation has increased, also due to new innovative companies and methods of innovation. These developments provide endless new opportunities and will enable us to better address global challenges across the board. However, each new opportunity can also challenge established business models, institutions and social structures, possibly affecting almost every aspect of life.

These drivers will shape a range of overarching **challenges** which Europe will have to face now and in the future.

The rapidly growing global population, combined with unsustainable production and consumption patterns, is putting our **planet under pressure,** to the extent that climate change is now considered an existential threat. As human activities touch or overstep planetary boundaries, we are depleting essential natural resources such as soil, water and air, threatening biodiversity and ecosystems, jeopardising the sustainability of our present standard of prosperity and wellbeing, and our ability to meet the needs of future generations. Our consumption of energy is a particular concern, as the development and use of sustainable energy sources and systems are struggling to keep up with a rising global demand. And the impact of climate change, already evident in extreme weather events such as droughts and wildfires across Europe, is increasing across the globe as the temperature rises. The United Nations Intergovernmental Panel on Climate Change has assessed that while the limitation of global warming is possible, doing so will require unprecedented changes in our ways of life, moving towards sustainable societies and economies.

Climate change and the transition towards sustainable development will affect many aspects of today's European society and economy, not least in coal- and carbon-intensive regions and sectors. While the transition will lead to wide-ranging changes in European industries, Europe also has a good starting point for transforming challenges into new opportunities and for disseminating solutions around the world. Europe is, perhaps more than any other part of the world, focused on furthering sustainable competitiveness, and European firms already represent five of the ten biggest clean-tech companies in the world. In other sectors, European businesses struggle to stay

competitive or scale up – for instance, there is no European company among the largest 15 companies in the digital sector. As technological developments become more and more important for **ensuring prosperity** and sustainable growth, Europe's technological sovereignty is at risk. This is not only a problem for European competitiveness and our ability to address the challenges of tomorrow, but potentially also European values, if these are not reflected in foreign technology.

Finally, these and other developments are creating an increasingly complex and ambiguous world, leading many citizens to experience justified insecurity about the changes to come. For instance, for the citizen, technological developments, particularly within robotics and digitalisation, will most likely require the acquisition of new skills and can raise legitimate concerns about the impact on employability and the quality of jobs in the future, and the wider implications for society. Increased mobility across borders, for instance within the Schengen area, while enjoyed by many citizens, also leads to concerns about the management and security of EU external borders. Demographic changes can increase pressure on public spending, for example, with people suffering increasingly from age-related diseases and disabilities which increase the demand for health and care services. And while the European values of respect for human rights, democracy and the rule of law are the foundations of our society, there are citizens who loose trust in these values and question the functioning of established institutions in the European Union and its Member States. Making sure we are putting **people at the centre,** focusing on citizens' needs and concerns while managing the transitions we are facing, is a central challenge in this regard.

These daunting challenges call for a radical new approach to developing and deploying new technologies and innovative solutions for citizens and the planet on a scale and at a speed never achieved before, and to adapting our policy and economic framework to turn global threats into new opportunities for our society and economy, citizens and businesses.

This requires stepping up and strategically planning research and innovation investments and supportive measures.

The description of drivers and challenges in this section is based on extensive analysis and foresight, including in: Beyond the Horizon: foresight in support of future EU research and innovation policy; Reflection paper: Towards a Sustainable Europe by 2030; Global Trends to 2030: Challenges and choices for Europe; Europe in May 2019: Preparing for a more united, stronger and more democratic Union in an increasingly uncertain world; The European Union: A people-centred agenda; OECD Science, Technology and Innovation Outlook 2016

3. The future we want - targeting the impact of Horizon Europe

A main objective of Horizon Europe, and in particular its second Pillar is *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.* [1]

Investing in research and innovation through Horizon Europe will thus help address the global challenges described in the section above as well as the United Nations Sustainable Development Goals (SDGs). It will impact on the direction and speed of the transitions we are facing, and on the rate at which business will develop, scale-up and commercialise innovative solutions. It is expected to play a vital role, in combination with other interventions, for creating new solutions and fostering innovation, both incremental and disruptive. At its simplest, Horizon Europe, and in particular its second Pillar, will help create a sustainable future where Europeans are healthier and more prosperous and live in a fair and inclusive society that achieves environmental sustainability and respects planetary boundaries.

However, it is not possible to do everything at once. In order to maximize the impact of Horizon Europe investments, it is necessary to strategically prioritise and direct a substantial part of the funds towards the areas where we believe they will matter the most, while building on the foundations of Horizon 2020 and exploiting links to other European policies and programmes[2]. While all elements of research and innovation have value in themselves, actions under Pillar II of Horizon Europe will target selected themes of especially high impact that significantly contribute to delivering on the political priorities of the Union.

Horizon Europe supports EU policy priorities
As a key source of new solutions, and an important and cross-cutting part of the EU Programmes, Horizon Europe plays a pivotal role in shaping, supporting and delivering on European policy priorities, in collaboration with Member States and future associated countries through the European Research Area.

In her Political Guidelines for the European Commission 2019 - 2024, the President of the European Commission has put forward six overarching priorities for the next five years, which reach well beyond 2024 in scope. The priorities build upon A New Strategic Agenda for 2019–2024, adopted by the European Council on 20 June 2019, which targets similar overarching objectives.

The six priorities of the Commission are:

1) A European Green Deal[3];
2) An economy that works for people[4];
3) A Europe fit for the Digital Age[5];

[1] Article 3, Common understanding regarding the proposal for Horizon Europe Framework Programme.
SMEs are Small and Medium-sized Enterprises.
[2] For example, Europe is investing in and acting upon challenges also through Smart Specialisation Strategies established under Cohesion Policy and activities carried out within the Horizon 2020 FET Flagships on Graphene, the Human Brain Project and Quantum Technology, will continue to be supported under Horizon Europe through calls for proposals included in the work programmes.
[3] In the New Strategic Agenda for 2019–2024 a similar priority, "Building a climate-neutral, green, fair and social Europe", is put forward.
[4] In the New Strategic Agenda for 2019–2024, this ambition is supported through the priorities "Developing a strong and vibrant economic base" and "Building a climate neutral, green, fair and Social Europe".

4) Promoting our European way of life[6];
5) A stronger Europe in the world[7];
6) A new push for European democracy[8].

Together with the SDGs, these priorities will shape future EU policy responses to the challenges we face and will steer the ongoing transitions in the European economy and society, EU research and innovation has an important role to play, by enabling, steering and supporting each of these priorities.

A prime example of a priority that will mobilise and steer many activities throughout Horizon Europe is **climate objectives;** at least 35 % of funding of the Horizon Europe Programme will be targeted climate objectives. A clear outcome of the co-design survey is that there is a strong demand for EU research and innovation to target the climate challenge and the corresponding policy priorities, while a key message from the European Research and Innovation Days was a call for Europe to take the lead on the **transition to sustainability**. Therefore, actions to address this challenge will be supported through a wide range of activities in Pillar II, such as developing new indicators for sustainable development (Cluster 2); improved disaster risk management for climate-related risks and extreme events (Cluster 3); combining earth observation from space with advances in the digital area to provide data for mitigation measures (Cluster 4); and protecting citizens' health from pollution (Cluster 1); to research and innovation activities more broadly aimed at providing solutions for a climate neutral and resilient society, for instance related to climate neutral industries, primary production based on sustainability and transport (Clusters 4, 5 and 6).

The figure and section below gives an indicative overview of how the political priorities of the Commission are supported by the targeted impacts proposed in this document. Please note however, that while each targeted impact is accounted for, and described under only one policy priority, most impacts are expected to contribute to more than one priority, in a complex and interconnected manner that cannot be described exhaustively in the following section.

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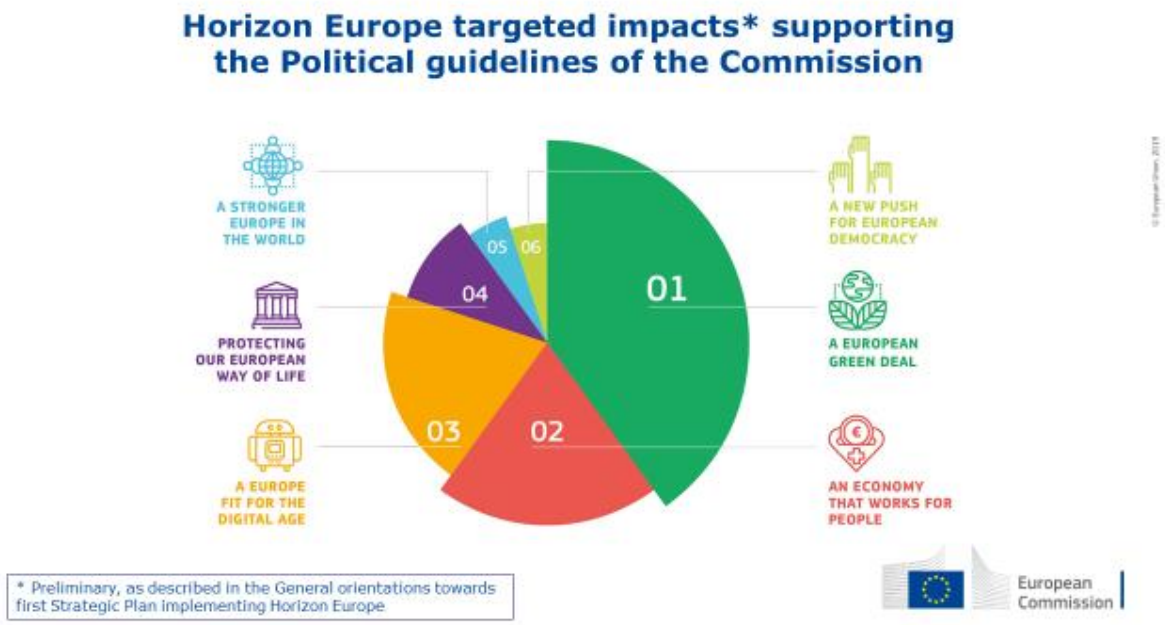
[5] In the New Strategic Agenda for 2019–2024, this ambition is supported through the priority "Developing a strong and vibrant economic base"
[6] In the New Strategic Agenda for 2019–2024 a similar priority, "Protecting Citizens and Freedoms", is put forward
[7] In the New Strategic Agenda for 2019–2024 a similar priority, Promoting European interests and values on the global stage is put forward
[8] In the In the New Strategic Agenda for 2019–2024, "Protecting Citizens and Freedoms", is put forward

Targeted impacts by priority



The main targeted impacts, as consolidated by the co-design process, for the first four years of Horizon Europe implementation and targeted from 2030 onwards, are presented in the next pages.

1) A European Green Deal

Policy objectives: Becoming the world's first climate-neutral continent is the greatest challenge and opportunity of our times. Preserving our natural environment and biodiversity and making Europe the world's first climate-neutral continent by 2050 requires changing the way we produce, trade and consume, and spurring on unprecedented technological, economic and societal transformations. Through the European Green Deal, the Union will lead global efforts towards circular economies and green and clean technologies and work to decarbonise energy-intensive industries. The Green Deal will also ensure that the ongoing sustainable transition is socially fair and leaves no citizen or region behind, while also protecting citizens' health from environmental degradation and pollution, and addressing air and water quality. What is good for our planet must also be good for our people, our regions and our economy, and research, innovation and development of new technologies, not least key enabling and digital technologies, are instrumental to achieving these ambitious goals.

Europe has a good starting point for this effort: In the area of climate change, the EU is at the forefront of implementing the Paris Agreement, and the Commission has adopted a vision for achieving a climate neutral economy by 2050. The EU also aims to lead the global community in developing and implementing a new approach to protecting biodiversity and planetary boundaries. Finally, efforts towards achieving climate neutrality also offers opportunities for new jobs and growth in European business and industry, for instance low-carbon industry, which is identified as a key strategic value chain.[9]

[9] More information regarding key strategic value chains available here: https://ec.europa.eu/growth/content/stronger-and-more-competitive-eu-industry-president-juncker-open-2019-eu-industry-days_en

These objectives also are reflected in especially SDGs 2 – Zero Hunger, 6 - Clean Water and Sanitation, 7 - Affordable and Clean Energy, 8 – Decent Work and Economic Growth, 9- Industry, Innovation and Infrastructure, 11 - Sustainable Cities and Communities, 12 -Responsible Consumption and Production, 13 - Climate Action, 14 - Life below Water and 15 - Life on Land.

Investment in the Horizon Europe missions concerning Adaptation to Climate Change, including Societal Transformation, Healthy Oceans, Seas, Coastal and Inland Waters, Climate-neutral and Smart Cities and Soil Health and Food will support this priority.

Investments in research and innovation concerning **health** (Cluster 1) will contribute to the zero-pollution ambition, especially through a cross-cutting strategy, to target the following impact:

- **Protection of citizens' health and well-being from environmental degradation and pollution**, including by addressing air and water quality, hazardous chemicals, industrial emissions, pesticides and endocrine disruptors. It will target healthy and health-promoting living and working environments and address climate related challenges to human health and health systems, e.g. related to heatwaves, the increasing causation of non-communicable diseases (incl. allergies and mental disorders) and the increased frequency of infectious diseases.

Investments in research and innovation concerning **digital, industry and space** (Cluster 4) will contribute to transforming the EU to a climate-neutral and circular economy, and target impacts especially in the following fields:

- **Climate-neutral, circular and clean EU industries**, for instance by creating plants in several regions with zero emissions and zero waste, to make decisive contributions to the fight against climate change and the protection of the environment; and develop and demonstrate breakthrough low-carbon processes, especially in the energy-intensive industries, and sustainable products;

- Increased autonomy in **critical raw materials**, through substitution, resource efficiency and recycling and primary production;

- **Greening ICT**, for instance by developing low energy consumption components and combination of approaches, to enhance the efficiency of computing by several orders of magnitude;

- **Technological and digital solutions contributing to the decarbonisation** of key economic sectors (e.g. energy, construction, transport) **and enabling sustainability;**

- **Space services** that contribute to climate mitigation and environmental protection, mobility and security.

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

- **Climate science and solutions for a climate neutral and resilient society**;

- **Novel competitive cross-sectoral solutions for decarbonisation** such as batteries, hydrogen, and other types of storage (chemical, mechanical, electrical and thermal), as well as sustainable buildings and infrastructure enabling low carbon solutions and other break-through technologies;

- **A cost-efficient, net zero-greenhouse gas energy system centred on renewables**;

- **Demand side solutions to decarbonise the energy systems**, mainly as regards buildings and industrial facilities;

- **Low-carbon and competitive transport solutions across all modes** (road, rail, aviation, and waterborne).

Investments in research and innovation concerning **food, bio-economy, natural resources, agriculture and environment** (Cluster 6) will advance knowledge, build capacities as well as develop and demonstrate innovative solutions to accelerate the transition to a sustainable management and use of natural resources from land and sea, ensuring ecosystem integrity as well as sustainable development and human well-being, including water, food and nutrition security, in the EU and globally. The following impacts will be targeted:

- Improved knowledge and innovations build the foundations for **climate neutrality** by reducing GHG emission and enhancing the sink and storage functions in production systems[10] and ecosystems, and foster **adaptation** of ecosystems, water management and production systems as well as of rural, coastal and urban areas to **climate change**;
- **Halt of biodiversity decline and restoration of ecosystems** enabled through improved knowledge and innovative solutions towards reaching the global vision for biodiversity 2050[11];
- Better understanding of planetary boundaries facilitates innovative solutions for **sustainable and circular management and use of natural resources** as well a**s prevention and removal of pollution,** guaranteeing healthy soils and clean water and air for all as well as boosting competitiveness, value creation and attractive jobs;
- Improved knowledge and innovations enhance **sustainable primary production[12], food and bio-based systems, which are inclusive, safe and healthy and** ensure food and nutrition security for all within planetary boundaries**;**
- Better understanding of the **behavioral, socio-economic and demographic changes** leads to innovative approaches that **drive sustainability** and **a balanced development of vibrant rural, coastal, peri-urban and urban areas**;
- Environmental observations, strengthened evidence base and tools are delivered and used for the **establishment and monitoring of governance models enabling sustainability**.

[10] Production systems related to sectors covered by Cluster 6

[11] "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people." CBD decision X/2. (Comment MF: This overarching vision will stay valid also if or the Biodiversity Strategy up to 2030, which targets will however only be adopted in autumn 2020)

[12] Primary production should be understood as agriculture, fisheries, aquaculture and forestry

2) An economy that works for people

Policy objectives: Our goal for a climate-neutral and healthy planet must be built on a strong and resilient social market economy. However, there is a need to prepare our technological and industrial future in a more strategic way, including incentivising and steering innovation, including social innovation, and facilitating the uptake of new technologies and innovative solutions. Our economic policy must go hand in hand with social rights, Europe's climate-neutrality objective and a competitive industry. Strengthening our social market economy is especially important at a time when we are redesigning the way our industry and our economy work.

The promotion of social cohesion and inclusiveness and the health and well-being of its people are central aims of the European Union's policies and programmes. With 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, also providing people with equal opportunities through access to education, training and life-long learning. To continue delivering on this agenda and to safeguard shared values and mutual trust, it is important to develop a Union of equality and to support Member States in addressing social challenges and inequalities, for example related to health, gender or education, within and across their territories and regions. In particular, a Europe's Beating Cancer Action Plan will support Member States in improving cancer control and care. Further efforts should also be devoted to making high-quality health care both available and affordable for citizens as well as to rendering health care systems more accessible and sustainable, including through the digital transformation of health and care.

These aims are also reflected in SDGs 1 – No Poverty; 3 – Good Health and Well-being; 4 – Quality Education; 5 – Gender Equality; 6 – Clean Water and Sanitation, 7 - Affordable and Clean Energy, 8 – Decent Work and Economic Growth; 10 – Reduced Inequalities; 11 – Sustainable Cities and Communities, and 16 – Peace, Justice and Strong Institutions.

Investment in the Horizon Europe missions concerning Cancer, Climate-neutral and Smart Cities and Soil Health and Food will support this priority.

Investments in research and innovation, in particular concerning **health** (Cluster 1) will target and contribute to the following impacts:

- **Healthy citizens in a rapidly changing society**: citizens stay healthier throughout the life course due to improved health promotion and disease prevention, and supported by healthier behaviours and lifestyles;

- **Effective health services to tackle diseases and reduce the burden of diseases**: patients can rely on effective health services to tackle their diseases, as well as to reduce the burden of diseases on them, their families and communities;

- **Improved access to innovative, sustainable and high-quality health care**: health systems are able to provide timely access to affordable health care services of high-quality to everybody while being environmentally and fiscally sustainable;

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

- **Reversing socio-economic, gender and cultural capital inequalities** via strategies of inclusion, non-discrimination, solidarity, social protection and social investment;

- **A comprehensive European strategy for inclusive growth** and upward convergence;

- **The value of European cultural heritage is safeguarded** by promoting the value, protection, access to and sustainable use of European cultural heritage and its contribution to the cultural and creative sectors.

Investments in research and innovation in particular regarding **digital, industry and space** (Cluster 4) will contribute to the following impact:

- **Increased inclusiveness**, by helping industry provide **attractive and creative jobs in Europe**; making a two-way engagement in the development of technologies a reality; developing human-centred approaches; promoting social innovation; and helping foster skills and empower the young in, for instance, the digital and advanced manufacturing areas.

3) A Europe fit for the Digital Age

Policy objectives: Digital technologies are transforming the world at an unprecedented rate, and Europe has the potential to become a world leader in the ongoing digital and industrial transformation. Europe needs to achieve technological sovereignty in critical technology areas such as high-performance computing, quantum computing, and the key technologies enabling them, by setting next generation standards and better coordinating and prioritising European investments in breakthrough technologies, in particular towards cybersecurity and human-centric and ethical artificial intelligence (AI). Many of these and other technologies will also support a wide range of policy priorities in strategic, industrial value chains and across sectors, such as health-care and transport.

To succeed in the digital transformation Europe should build on its strengths and values and empower people through education, life-long learning and the development of new skills, which drive Europe's competitiveness and innovation. For instance, digital literacy, for both young and old, will be developed as part of the European Education Area that should become a reality by 2025.

The renewed EU Industrial Policy Strategy also shows how the EU must tackle missing segments in key strategic value chains if its industry is to stay competitive, embrace the digital transformation and become 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: from secure and sustainable supply of raw materials, maximising the value of its resources and materials, to key enabling and digital technologies.

These aims are also reflected in SDG 9 – Industry, Innovation and Infrastructure.

Investment in research and innovation regarding **health** (Cluster 1) will support the following targeted impacts:

- **Unlocking the full potential of new tools, technologies and digital solutions for a healthy society**: new tools, technologies and digital solutions provide significant gains in health outcomes, address unmet medical needs and inform regulatory standards and requirements; (also contributing to an economy that works for the people);

- **A sustainable and globally competitive health-related industry in the EU**: health industries, including SMEs, increase their productivity and sustainability in developing relevant health innovation due to the potential of data-enabled research and development, the related convergence of pharmaceutical, digital and medical technologies, and the prospect of the digital transformation of health and care supported by data-driven manufacturing of tailor-made products and the delivery of personalised services.

Simultaneously and interactively, ***investments in research and innovation*** concerning **culture, creativity and inclusive society** (Cluster 2) will target and contribute to

- **Improved approaches in addressing the societal – including political, ethical and economic – effects of technological advancements and the impact of drivers of change** on jobs, skills, productivity, income, education, welfare and inequalities.

Further ***investments in research and innovation*** in particular regarding **digital, industry and space** (Cluster 4) will contribute to the following impacts:

- **Digitising and transforming industry**;

- **Increased sovereignty** in **key enabling technologies and digital technologies**, in strategic value chains, and a **secure, sustainable and responsibly-sourced supply of raw materials**;

- **A European approach**, involving a human-centred and ethical development and use of new technologies;

- **Industrial leadership** in **key enabling and digital technologies, uptake of new technologies, and space services and data,** through technology infrastructures and autonomy in strategic value chains.

Finally, ***investments in research and innovation*** regarding **climate, energy and mobility** (Cluster 5) will target and contribute to:

- **Seamless, smart, safe, accessible and inclusive mobility systems** to reap the benefits of digitalisation, increase efficiency and European competitiveness, enable better and sustainable door-to-door mobility for all and increase safety;

- **Smart and cyber-secure energy grids** to enable more interaction and utilisation between producers, consumers, networks, infrastructure and vectors.

4) Promoting our European way of life

Policy objectives: While the establishment of the European Union in itself has brought unprecedented peace and prosperity, 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 SDG 16 – Peace, Justice and Strong Institutions.

There are a number 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, on security (including cybersecurity) of infrastructure and on 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, such as the Directive on security of network and information systems (NIS Directive) and the EU Cybersecurity Act, and online privacy.

Research and innovation activities can support these policies in various ways. ***Investments in research and innovation***, in particular concerning **culture, creativity and inclusive society** (Cluster 2) will target and contribute to:

- **Increased use of evidence-based strategies in the management of mobility and migration and the integration of migrants in European society,** including a better understanding how migration interacts with other relevant policy fields (e.g. welfare, education, skills provision, housing).

Investments in research and innovation in particular within **civil security for society** (Cluster 3) will contribute to creating *'a resilient and more stable Europe that protects',* especially with the following impacts:

- **Improved disaster risk management and societal resilience** through better understanding of natural and man-made disasters and by the development of novel concepts and technologies to counter these risks;

- **Improved management of EU external borders** (air, land and sea) by the development of tools and concepts towards an Integrated Border Management, including better knowledge of societal factors with regards to border security;

- **Better protection of public spaces** through enhanced detection, a more secure design assisted by comprehensive vulnerability assessments and with quicker response to threats without compromising the open character of such spaces;

- **Improved security and resilience of infrastructure and vital societal functions** enabled by improved risk assessments and more efficient response to disruptions with a view of quickly restoring performance levels;

- **Improved maritime security** based on the EU Maritime Security Research Agenda to counter threats such as trafficking, piracy as well as cyber and hybrid threats;

- **More effective fight against crime and terrorism** by better understanding of societal factors leading to radicalisation and crime, and by developing state of the art capabilities for Law Enforcement Agencies in the EU, notably against cybercrime;

- **Increased cybersecurity** based on more effective use of digital technologies, strong orientation on privacy and fundamental rights and a robust digital infrastructure to counter cyber-attacks.

5) A stronger Europe in the world

***Policy objectives**:* In an increasingly fractured and multipolar world threatened by global challenges, the EU will need to ensure its future prosperity and to seek a leading role in driving global efforts towards sustainability.

The EU approach to research and innovation has long been one of openness to the world to maximise our access to the latest scientific knowledge and international value chains, and to tackle global challenges together. The EU needs to build upon and further intensify this to fully benefit from new global opportunities, by pursuing strategic partnerships with key partner countries, and by promoting international cooperation based on common research and innovation principles, mutual benefits, EU interests, international commitments and, where appropriate, reciprocity,. The growing role of science diplomacy as a key element of EU external action should also foster mutual understanding, stability and progress.

International programmatic coordination through multilateral initiatives is increasingly used to tackle global challenges more effectively, such as those related to climate change, food and water security, environmental degradation, pollution and threats to global health. The expanding scope and interconnectivity of these challenges require the EU to strengthen its role in multilateral and bilateral setups while also asserting EU values and interests more pro-actively, 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. More broadly, these aims also support SDG 17 – 'Partnerships for the Goals'.

Investment in international actions in research and innovation, cutting across all clusters, will contribute to achieving targeted impacts such as:

- **Strengthened scientific and technological links with key partners** through policy dialogues and strategic partnerships in research and innovation in areas of mutual benefit and common interest;

- **Multilateral alliances to address key objectives** such as more effectively tackling environmental pollution, antimicrobial resistance, (re)emerging infectious diseases, epidemic outbreaks and other risk factors and threats to global health, gaining access to and share environmental observation data, or contributing to international climate and environmental assessments;

- **An international level playing field and reciprocity** through industrial and policy dialogues in areas such as safety standards and the life-cycle assessment of materials, and the regulatory context of manufacturing, digital technologies, and consumer products and services;

- **Commonly accepted ethics approaches for scientific knowledge and the development of technologies such as Artificial Intelligence** through science governance dialogues including for example the promotion of guidelines for research ethics and integrity, and the promotion of ethics by design principles.

6) A new push for European democracy

Democracies have come under pressure in recent times. Political distrust, polarizing discourses, lower electoral participation and populist narratives that reject the idea of an open society manifest themselves in Europe and beyond. Action is therefore needed to re-invigorate and modernise democratic governance. The aim is to contribute to the development of policies, innovations and institutions that expand political participation and civic engagement, enhance accountability and legitimacy, protect rights and the rule of law and help restore trust in democratic institutions.

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

- **Enhanced democracy and governance** through bolstering the accountability, legitimacy, transparency and effectiveness of democratic systems and the protection of fundamental rights and the rule of law;

- **Better approaches to tackling political extremism and polarisation** by strengthening democratic participation and active citizenship, fostering awareness and exercise of democratic rights, and understanding the role of media in fostering or inhibiting political dialogue.

4. Supporting research and innovation policy priorities through Horizon Europe - Specific issues

The impact and added value of European research and innovation investments will also depend on our capacity to leverage a number of cross-cutting factors when implementing Horizon Europe, ranging from core EU values to legal and operational provisions:

- The inclusion of gender perspectives will enable better quality and higher societal relevance of research and innovation activities.
- Interdisciplinarity and inclusion of Social Sciences and Humanities (SSH) aspects is a prerequisite for addressing a number of societal challenges, which are cross-cutting by nature and should be actively implemented throughout the whole research programme.
- The mainstreaming of open science across activities will increase efficiency, quality, reliability and creativity of research and innovation, enhance transparency and relevance and enable dissemination of results.
- Dissemination and exploitation of results will be supported through targeted support actions to reach relevant stakeholders.
- Circulation of knowledge between research, industry, education and training, and the balance between research and innovation, is ensured throughout the design of Horizon Europe activities.
- Key enabling technologies will be supported to enhance Europe's competitiveness in strategic value chains.

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 that works for all. It is also an ambition of the Commission to foster a Union of Equality that includes and goes beyond gender equality.

Activities will aim at eliminating gender inequalities throughout research and innovation systems, including by addressing unconscious bias, 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 health and care, cyber-violence, artificial intelligence and robotics, or else climate change and mitigation, in which sex and/gender differences play an important role in research design/content, and hence determine the societal relevance and quality of research and innovation outcomes.

The challenges we are facing today are of such a nature that few can be addressed through one scientific discipline alone. **Social Sciences and Humanities** (SSH) are key to understanding the relationships between human behaviour and major global challenges, but also to the effectiveness of the solutions we propose to address them. For instance, SSH can contribute to our understanding of how best to engage with citizens in tackling pressing societal concerns such as climate change and the related need for adaptation, as well as how to exploit new technologies in a way that is focused on citizens' needs and concerns.

In addressing and understanding citizens' expectations and preoccupations, SSH contributes substantially to strengthening society's ability to embrace and drive change, whether economic, social, or technological or cultural, and thus to achieving many targeted impacts across the programme. Furthermore, SSH helps to better understand the socio-economic outcomes of research policy itself and to enhance its societal impact in the future. Finally, SSH is a key element in fostering the necessary behavioural change in a number of important areas, such as mobility i.e. achieving a socially acceptable, environmentally responsible and fair transition towards new modes of transport.

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 common interoperable framework for federating infrastructures, platforms and associated services for data-driven research for all researchers and innovators, and responsibility and openness of science towards society and vice versa. Open access to research data will be the general rule, ensuring the

possibility of exceptions following the principle 'as open as possible, as closed as necessary'. Open science will increase the quality of science and productivity of research and will accelerate the pace and uptake of innovation to deliver on societal, economic and technological challenges. It also promises to give Europe a global lead in research data management. Engaging and involving citizens, civil society organisations and end-users in co-design and co-creation processes and promoting responsible research and innovation will improve trust between science and society, as well as the uptake of scientific evidence-based public policies and innovative solutions.

Throughout the programme, attention will be paid to and specific actions will be launched for promoting **ethics and research integrity** and continuing to develop a coherent framework of adherence to the highest ethics standards and to the principles embedded in the European Code of Conduct for Research Integrity. This will include actions addressing the ethical dimension of new technologies, notably those related to Artificial Intelligence and their potential societal impact as well as work on research ethics in the environment protection. Further developing cooperation between the research ethics and integrity actors involved at regional and national levels will also be a focus.

Activities to **disseminate and exploit results** from research and innovation will be an integral part of Horizon Europe. Enhanced dissemination and exploitation are strategic matters for the success of Horizon Europe, synergies with other programmes and for the achievement of impact on society at large. One of the most efficient ways of furthering dissemination and exploitation of research results is through education and training. When new discoveries and knowledge are integrated in education activities, students at all levels are able to bring state-of-the-art knowledge with them to workplaces across society.

In addition to the initiatives towards open science mentioned above, Horizon Europe introduces novelties in the way research and innovation results are disseminated and exploited, giving more emphasis to third party uptake with private investments and to the knowledge and impact these results create after the end of research and innovation projects.

Against this background, and in line with Horizon Europe's overarching objective of enhanced communication and engagement with the public, dedicated activities for the visibility, use and valorisation of research and innovation results, including mission outputs will be introduced. Horizon Europe will ensure support to beneficiaries for their dissemination and exploitation activities during and after their project lifetime. Furthermore, a framework for feeding consolidated outcome based on research and innovation results, into policy and decision making will be proposed.

The availability of top-quality talent and the **effective circulation of knowledge between research, industry, education and training** is a pre-requisite for maximising the impact of European research and innovation investments. Integrating research and innovation activities with education and training, and supporting activities for knowledge exchange and transfer across sectors, for instance via Marie Skłodowska-Curie Actions and Knowledge and Innovation Communities, is a powerful method to ensure research and innovation activities are informed by and directed towards citizens' and society's needs and the results are widely disseminated, for instance through a well-educated work-force. **A balanced approach between research and innovation** is a central part of Horizon Europe, built into in the design which spans the full range of Technology Readiness Levels (TRLs) from curiosity-driven research to commercially-driven innovation and support to market deployment, and within innovation, technological, non-technological and social innovation.

In many instances, new discoveries within basic research create the foundations for research and innovation impacts and lead to a 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 towards giving EU industries the competitive edge they need for industrial leadership in global markets and promise breakthroughs to solving global challenges and achieving 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, Pillar I of Horizon Europe, Excellent Science, while bottom-up in nature, 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.

Furthermore, some ongoing investments in science under the **FET Flagships** with breakthrough potential for Europe will keep being supported under Horizon Europe. First, Quantum Technologies through the development of a quantum web, where quantum computers, simulators and sensors are interconnected via quantum communication networks. Second, Graphene, aiming at scientific breakthroughs in graphene and other 2D materials, while further advancing components based on these materials for applications in areas such as energy, electronics, sensors and biomedical technologies. Finally, the Human Brain Project will aim at achieving a comprehensive understanding of the human brain and its diseases by combining neuroscience with advanced ICT, enhancing and operating a sustainable and open European Research Infrastructure. Preparatory actions supported under the FET Flagships part of Horizon 2020 will also e.g. inform the work on missions, co-funded/co-programmed partnerships and regular calls for proposals.

5. Coordination of relevant activities within Horizon Europe – maximizing added value through a coordinated approach

Horizon Europe is comprised of three distinct Pillars, supported by activities to widen participation and strengthening the European Research Area (ERA), each part contributing to the common Horizon Europe objectives. While the Strategic Planning process focuses on the activities within Pillar II, 'Global challenges and European industrial competitiveness', coordination is sought with relevant activities in other parts of the programme in order to maximize added value and impact overall.

Pillar I – Excellent Science
Pillar I aims to promote scientific excellence, the creation and diffusion of new knowledge, skills, technologies and solutions as well as the access to and the development of world-class research infrastructures, and boost the training and mobility of researchers, thus raising the attractiveness of the European Research Area.

Pillar I will form an important part of the foundation for the long-term excellence and capabilities of European science. Pillar I is largely bottom-up and focuses especially on enabling and supporting the next generation of science, technology, researchers and innovations. It thus opens the way to new and often unexpected scientific and technological results, which can also drive forward the Horizon Europe objectives of enabling innovation and business inventiveness and contribute to tackling global and societal challenges, including to help missions achieve their goals.

The European Research Council (ERC) will continue to pursue ground breaking, high-gain/high-risk research and to advance the frontiers of knowledge.

ERC will also share experience and best practices with regional and national research funding agencies and build links to other parts of Horizon Europe, in particular Marie Skłodowska-Curie Actions, to promote the support of excellent researchers. A new generation of highly-skilled researchers and emerging talent from across the EU and beyond, could be guided towards ERC funding. Innovations stemming from the ERC, including from its Proof of Concept Grant could be taken up by the European Innovation Council's Accelerator.

The Marie Skłodowska-Curie Actions (MSCA) will continue to fund, support and train the people and institutions behind research and innovation, strengthening excellent doctoral and postdoctoral training programmes, as well as researcher training and career development systems across the ERA, in a fully bottom-up and competition- for- excellence-based manner. The Commission intends to enable cross-fertilisation between the bottom-up MSCA research and training projects and the need for skills in areas or projects identified in the Strategic Plan. To this end, MSCA projects in such specific areas may be invited to a broader community of, for instance, mission activities. Where relevant, MSCA projects could also align skills training with specific needs of the mission portfolios.

Research Infrastructures actions support the provision of state of the art services, knowledge, and tools to address societal challenges, ensure evidence-based policy making and help industry to strengthen its base of knowledge and technical know-how. Research Infrastructures will thus substantially contribute to the objectives of the clusters and missions supported in Horizon Europe and to the SDGs. Research Infrastructures actions, in cooperation with the European Strategy Forum on Research Infrastructures (ESFRI), contribute to reduce fragmentation and to consolidate the landscape of European, national and regional infrastructures. As these research infrastructures will be connected to the European Open Science Cloud (EOSC), researchers involved in Horizon Europe activities will have access to most of the data generated and collected by research infrastructures as well as to high performance computing (HPC) and exascale resources deployed under the European Data Infrastructure (EDI). The use of existing research infrastructures will be stimulated across the different pillars of Horizon Europe, for an effective and efficient use of resources and investments.

Pillar III – Innovative Europe
Pillar III aims to reinforce the innovative capacities of Europe, through supporting the development and deployment of disruptive and market-creating innovations, enhancing the overall European innovation landscape by linking together European ecosystems, and reinforcing the synergies between academia, entrepreneurs, not least SMEs, and market operators.

Europe is stronger in research than in innovation. Despite some encouraging signs – for instance, the number of European start-ups valued over 1 billion dollars (so-called unicorns) has more than doubled in the last few years, and more than 1/3 of young companies in cleantech with high investor appeal are European – in many areas, Europe is lagging behind global competitors in terms of capacity to turn scientific excellence into innovation and businesses. More needs to be done to start regaining European sovereignty and leadership in breakthrough technologies and disruptive, market creating innovations that will impact the European way of life and the well-being of our citizens.

The European Innovation Council (EIC) will enhance Europe's capabilities at the forefront of the next wave of disruptive, market-creating innovation. It will be the one-stop shop for enabling inventors, innovators and investors to bring the most promising ideas to real world application, and will support the scaling-up of innovative start-ups and companies. The EIC will thus play an important role in further nurturing and deploying disruptive or market creating innovations wherever they originate from, notably from other Pillars of Horizon Europe:

The EIC's *Pathfinder* will actively support the development of breakthrough technologies, which are key to disruptive innovations. Whilst essentially bottom-up, the Pathfinder will also operate on a top-down basis to build up, where needed, its thematic based portfolios of projects. To that end, it will operate in close coordination with other initiatives supported by Clusters of Pillar II, to avoid any overlap and ensure an overarching coordinated management where appropriate.

The EIC's *Accelerator* will bring any market creating innovation, including social innovation, closer to market operators and investors and support the scaling-up of companies, on a bottom-up basis. In this context, it will also provide support for the market deployment and scale up of other Pillar's emerging innovations and companies, in particular Pillar II. But the Accelerator may also focus via top-down calls on emerging, market-creating and/or deep-tech areas of potential strategic significance, also covered by other parts of Horizon Europe, in particular Pillar II Clusters and missions. In such cases, the Accelerator will always operate in conjunction (e.g. related to planning, budget) with these.

The **European Innovation Ecosystem** part of Pillar III will strive to enhance the overall European innovation landscape, complementing the targeted support delivered by the EIC. It will connect all actors - public and private, national and local - of the innovation ecosystems in Europe, including EIC actors, to share best practices and resources and enhance opportunities offered to all European innovators for developing and deploying their products in order to contribute to the development of a level-playing field across Europe. Activities will include the support to joint programmes supporting innovation activities, from training to projects and scale-ups, implemented by national or local actors.

Furthermore, while the innovation ecosystems activities are open to all High Growth Innovative companies[13] in Europe, specific tools such as the Horizon Results Platform and the Innovation Radar will be used to ensure that eligible Pillar II results and companies are adequately supported by these activities.

[13] Companies in innovative sectors which have grown by10 - 20%, annually on average for the past three years, either in terms of employment or turnover, and had at least 10 employees at the start of the growth period.

The challenge-driven approach of the **European Institute of Innovation and Technology (EIT) Knowledge and Innovation Communities' (KICs)** 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, can contribute to the objectives of the Pillar II and complement its relevant activities to address the key cross-cutting priorities beneficial for society such as addressing climate change, supporting the digital economy, innovative energy, health or sustainable development of cities. In particular, EIT KICs can mobilise a wide range of stakeholders (e.g. companies, universities and research centres, cities and regions, and financial partners) within their ecosystem to participate in the activities that will contribute to achieve objectives of the relevant missions and thematic clusters as well as other European Partnerships.

Relevant activities in the part Widening Participation and Strengthening the European Research Area

The excellent and responsible research, cross-border collaboration and ground-breaking innovation supported by Horizon Europe will, in different ways, strengthen and reinforce research and innovation systems across all Member States and Associated Countries.

Measures supported under the part **Widening participation and spreading excellence** will over time underpin and amplify the impact of Horizon Europe by helping countries that are lagging behind, including the EU outermost regions, to contribute to actions under other parts of Horizon Europe.

This could be achieved by a wide range of activities including enhancing research and innovation capacity, spurring national reforms, facilitating brain circulation, launching measures for promoting excellence, creating new collaborative networks across the EU and supporting the opening of established networks to applicants from widening countries.

Impacts will range from creating new or upgrading existing centres of excellence (Teaming) and significantly improving the research and innovation capacity of universities and research organisations (Twinning) to attracting and maintaining high quality human resources in research organisations ('ERA Chair holder') and ensuring scientific networking, capacity building and career development support to researchers at all career stages (COST actions).

The part on **Strengthening the European Research Area** will support a new phase in the development of the European Research Area and synergies with the European Higher Education Area, which may include a stronger focus on supporting the challenges identified in Pillar II, including missions and partnerships, to ensure that the strategic investments made there deliver maximum impact.

Opening the European Research Area to future challenges requires developing synergies with the European Higher Education Area in a complex landscape of universities and research organisations with a view to underpinning open science, innovative entrepreneurial practices, life-long-learning and upskilling talent and breaking down disciplinary and inter-sectoral barriers to match emerging business and societal needs.

Impacts will include better alignment of national reforms and increased programme level collaboration across Member States and Associated Countries, and will help increase the impact of both national and European investments in research and innovation. This will also support other research and innovation priorities including Open Science, citizens' science, gender equality and other forms of diversity, improving international cooperation, ethics and integrity, and scientific input to other EU policies.

In addition, the evidence base for policymaking across all these domains will be further developed, including through economic analysis of research and innovation policies and performance, design of research and innovation strategies, work to refine indicators and to develop new ones, when needed in cooperation with international organisations and foresight.

6. New approaches and instruments for maximising impact – missions and partnerships

Horizon Europe uses a variety of targeted instruments and approaches to more efficiently direct research and innovation investments and maximise the impact of investing public funds towards achieving global challenges and European policy objectives. Among the tools to implement the programme are missions and partnerships, missions being a completely new approach, while the approach to partnerships has gone through a major reform based on the experience of Horizon 2020.

The common aim is to tackle global challenges, in particular in line with the SDGs, in a coordinated way through creating scale and critical mass, integrating demand-side policies and engaging with citizens and end-users.

The transitions we are facing, including towards a greener, socially relevant and digitally-enabled economy, requires coordinated joint research and innovation efforts of the public and the private sector, and a contribution from citizens and users in co-creating solutions. **Partnerships** allow to forge such coalitions and create large scale testing and experimental platforms to develop systemic innovative solutions for societal challenges and industrial transformation. Missions will spark and steer new research and innovation activities to achieve targeted, ambitious and measurable goals which speak to citizens, engaging with and leveraging policies and actors well beyond research and innovation.

The details and subjects to be covered by future European Partnerships and missions are being developed through specific processes, closely involving Member States and stakeholders more broadly, and as part of strategic planning. More information regarding missions and partnerships can be found in Annex 7.

In the preparation of the work programmes and other relevant acts, an integrated and coherent vision will be maintained in order to avoid duplications or omissions in the actions carried out within missions, partnerships, Knowledge Innovation Communities, the EIC programmes and other calls for proposals.

6.1 Missions

One of the main novelties of Horizon Europe is the introduction of missions: high-ambition, high-profile initiatives which will put forward concrete solutions to challenges facing European citizens and society. Missions are intended to achieve a measurable goal within a set timeframe, with impact for science and technology and/or society and citizens that could not be achieved through individual actions. They are currently in the process of being defined and should stem from the following mission areas, which have been defined in the Horizon Europe agreement by Council and Parliament in 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

6.2 Partnerships

European Partnerships are initiatives where the EU together with private and/or public partners commit to jointly support the development and implementation of a programme of research and innovation activities. The partners could represent industry, universities, research organisations, bodies with a public service remit at local, regional, national or international level or civil society organisations including foundations and NGOs.

Their added value lies in particular in bringing together a broad range of actors to work towards a common vision and translating it into concrete roadmaps and coordinated implementation of activities. Partnerships allow to cover a broad set of activities from funding research and innovation projects to those related to societal, regulatory and market uptake, and developing synergies with national and regional programmes to ensure deployment and scaling up of new clean technologies and solutions. As such, they are powerful approaches for providing solutions to global challenges and drive transformation towards achieving the SDGs.

European Partnerships will be established only in cases where they will achieve objectives of Horizon Europe more effectively than what can be achieved by other activities of the framework programme. They need to adhere to the principles of Union added value, transparency, openness, impact within and for Europe, a strong leverage effect at a sufficient scale, long-term commitments of all the involved parties, flexibility in implementation, coherence, coordination and complementarity with Union, local, regional, national and, where relevant, with international initiatives or other partnerships and missions. They also need to have a clear life-cycle approach, be time limited and include conditions for phasing out the Programme funding.

European Partnerships may take any of the following forms:

Co-programmed European Partnerships: Based on a memoranda of understanding and/or contractual arrangement between the Commission and private and/or public partners, specifying the objectives of the partnership, related commitments from all involved sides for financial and/or in-kind contributions of the partners, key performance and impact indicators, outputs to be delivered and reporting modalities. They include the identification of complementary research and innovation activities that are implemented separately by the partners and by the EU through work programmes (comitology procedure);

Co-funded European Partnerships: Based on grant agreement between the Commission and the consortium of partners, resulting from a call for proposals for a programme co-fund action in the work programme of Horizon Europe. The programme needs to specify the objectives, key performance and impact indicators, and outputs to be delivered, based on the commitment of the partners for financial and/or in-kind contributions and integration of their relevant activities. Suited to partnerships involving public authorities, but possible also to include foundations and international partners;

Institutionalised European Partnerships: Research and innovation programmes undertaken by several Member States, based on a Decision by the Council and European Parliament in accordance with Article 185 TFEU, or by bodies established through a Decision of the Council pursuant to Article 187 TFEU, such as Joint Undertakings, or by EIT Knowledge and Innovation Communities in compliance with the EIT Regulation and the EIT Strategic Innovation Agenda (SIA). Such partnerships will be implemented only where other forms of European Partnerships would not achieve the objectives or generate the expected impacts, and if justified by a long-term perspective and high degree of integration.

In the summer of 2019, the Commission has proposed to explore the possibility of 44 European Partnerships. The co-design exercise confirmed that these candidates are relevant for addressing with a partnership approach. Four new candidates for European Partnerships have been included to the portfolio as a result of the strategic coordinating process (One Health AMR, Geological Service for Europe, Sustainable, Smart and Inclusive Cities and Communities and Zero-emission Waterborne Transport).

In addition, a new KIC for creative and cultural industries has been proposed by the Commission in the EIT Strategic Innovation Agenda for 2021-2027, subject to ongoing negotiations in the Council and European Parliament. The current list of candidate European Partnerships is described in **Annex 7**.

The Commission is expected to adopt to the proposals for Institutionalised European Partnerships (based on Articles 185 and 187 TFEU) before the summer 2020, after completing impact assessments for these partnerships. The identification of Co-programmed and Co-funded European

Partnerships in the Strategic Plan will take into account the progress made with potential partners, in particular vis-à-vis meeting the conditions and criteria of Horizon Europe. It will also be influenced by the outcome of the impact assessments of Institutionalised European Partnerships (based on Articles 185 and 187 TFEU).

7. Summary of cluster-specific orientations (annexes 1 - 6)

Cluster 1, '**Health**', aims to promote and protect human health and well-being, prevent diseases and decrease the burden of diseases and disabilities on people and communities, support the transformation of health care systems in their efforts towards fair access to innovative, sustainable and high quality health care for everyone, and foster an innovative, sustainable and globally competitive European health industry. Research and innovation actions under this cluster will be key to address the health-related challenges and drivers delivering new knowledge and capabilities, improving our understanding of health and diseases, developing innovative methodological and technological solutions to better manage health and diseases, and designing sustainable approaches for the digital transformation and delivery of integrated, person-centred and equitable health and care services with improved accessibility and health outcomes supported by needs-driven innovation and reliable supply chains in Europe.

Cluster 2, '**Culture, Creativity and Inclusive Society**' aims to meet EU goals and priorities on enhancing democratic governance and citizens participation, and on the safeguarding and promotion of cultural heritage, and to respond to multifaceted social, economic, technological and cultural transformations. Activities will contribute to expanding civic engagement, boosting transparency, accountability, inclusiveness and legitimacy of governance, improving levels of trust and tackling political extremism. Activities within the Cluster will also promote better access and engagement with cultural heritage and improve its protection, enhancement and restoration. Research and innovation will support sustainable growth and job creation through contributing to a European industrial policy for the cultural and creative industries. At the same time, actions will help tackle social, economic and political inequalities, support human capital development and contribute to a comprehensive European strategy for inclusive growth. This also involves understanding and responding to the impacts of technological advancements and economic interconnectedness with a view to social resilience. Finally, the Cluster will support EU migration and mobility policies, both internal and external, while aiming to promote integration.

Cluster 3, '**Civil security for Society**', aims to contribute to protecting the EU and its citizens from the threats posed by crime and terrorism (including in the cyber environment) and from the impacts of natural and man-made disasters. As shown in Eurobarometer surveys, security is one of the main concerns of EU citizens and is therefore among the top priorities for the Commission. Modern security threats are evolving rapidly, and technological and societal changes are creating unprecedented complexity, but so also are opportunities for addressing them more efficiently. In this regard, security research provides the resources to be able to adequately counter current threats, by enabling the availability of state of the art equipment and knowledge. Furthermore, by working to anticipate future threats, security research develops today the capabilities that will be needed in the future.

Cluster 4, '**Digital, Industry and Space**' will advance key enabling, digital and space technologies, underpinning the transformation of our economy and society, support the digitisation and transformation of European industry and contribute to securing global industrial leadership and autonomy / sovereignty in terms of technologies and resources. Furthermore, activities with the Cluster will contribute to growing a low-carbon, circular and clean industry respecting planetary boundaries and to fostering inclusiveness in the form of high-quality jobs and societal engagement in the use of technologies. Thereby it will contribute to addressing the challenges European industry is facing, such as its reliance on imported key technologies and raw materials, the scarcity of resources including energy, as well as skills mismatches and ethical considerations relating to technological progress.

Cluster 5, '**Climate, Energy and Mobility**', aims to fight climate change while improving the competitiveness of the energy and transport industries as well as the quality of the services that these sectors bring to society. This entails establishing a better understanding of the causes, evolution, risks, impacts and opportunities of climate change, as well as making energy and mobility systems climate- and environment-friendly, smarter, safer, and more resilient, inclusive, competitive and efficient. Actions of this Cluster will contribute to the technological, economic and societal transformations required to achieve climate neutrality, adapt to the locked-in changes that are coming to our climate, and to ensure a socially fair transition, as outlined in the Commission's long-term strategy (adopted in November 2018).

Cluster 6, '**Food, Bioeconomy, Natural Resources, Agriculture and Environment**' will advance knowledge, expand capacities and deliver innovative solutions to accelerate the transition

towards the sustainable management of natural resources (such as biodiversity, water and soils). This will include measures for: climate adaptation and climate neutrality of sustainable primary production (agriculture, forestry, fisheries and aquaculture), value chains, food systems and bio-based industries; optimising ecosystem services including for climate mitigation; reversing biodiversity decline; and reducing environmental degradation and pollution. Activities will benefit people and society by promoting safe and healthy food as well as human well-being, including through a better understanding of consumer behaviour. Furthermore, activities will help to develop vibrant rural and coastal areas and to establish governance models for the transition towards sustainability. To this end, actions under this Cluster will lead and support the switch to a competitive, more circular and bio-based, climate-neutral, resilient and environmentally-friendly economy in compliance with the Paris Agreement on Climate Change and the SDGs.

ANNEX 1 - CLUSTER 1: HEALTH

1. Global Challenges and their Drivers

Diseases and disabilities pose a major societal and economic burden on citizens and health systems of the EU and worldwide. Non-communicable diseases, including mental disorders and illnesses, are currently responsible for up to 80% of health care costs in the EU[14]. This will further increase should the ageing society[15] not adopt healthier lifestyles and more effective health care approaches. Likewise, infectious diseases, including antimicrobial resistant infections, represent a major health risk to people as well as a serious cross-border health security threat for countries in the EU and worldwide. These challenges call for more health promotion, better disease prevention and more effective solutions to manage diseases and reduce disease burden as well as 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 high quality to all citizens. To that end, new approaches for integrated, person-centred and equitable health care are required, which take into account specific needs of citizens and population groups throughout the life course, the influence of environmental, behavioural and socio-economic risk factors on human health and well-being, the opportunities offered by new tools, technologies, and digital solutions, and are built on a competent, reliable, secure and competitive European system of health care service developers, suppliers and providers.
Research and innovation will be instrumental to develop these new approaches as well as to increase the knowledge, understanding and know-how that underpin innovation for promoting health and for preventing, treating, curing and recovering from diseases, including rehabilitation, reintegration and survivorship. It will also require that new, better and more cost-effective health care services supported by innovative tools, technologies, and digital solutions become available that respond to the health needs of citizens and populations for promoting and protecting their health, preventing and managing their 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, and contributing to the European Health Data Space[16]. Cooperation with other sectors will maximise societal benefits, drive innovation and ensure optimal impact. Accordingly, research and innovation interventions under Cluster 1 Health will be oriented towards the following six health-related challenges (targeted impacts):

- 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;
- Unlocking the full potential of new tools, technologies and digital solutions for a healthy society;
- Maintaining a sustainable and globally competitive health-related industry.

These challenges are complex and interdependent. They have been chosen because they address key concerns and provide a clear perspective on what benefits people, patients and populations as well as institutional, social and economic stakeholders can expect from research and innovation interventions supported under this cluster. Moreover, there are challenges transcending both national and continental boundaries and requiring international approaches to address them

[14] Non-communicable - or chronic - diseases are diseases of long duration and generally slow progression, and are the result of a combination of genetic, physiological, environmental and behavioral factors. The four main types of non-communicable diseases (NCDs) are cardiovascular diseases (like heart attacks and stroke), cancer, chronic respiratory diseases (such as chronic obstructed pulmonary disease and asthma) and diabetes. NCDs are by far the leading cause of death in the world, representing 63% of all annual deaths. NCDs kill more than 36 million people each year. Some 80% of all NCD deaths occur in low- and middle-income countries. https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases

[15] The share of the population aged over 65 on average across EU countries has increased from less than 10% in 1960 to nearly 20% in 2015 and is projected to increase further to nearly 30% by 2060.

[16] Mission letter of the Commissioner for health, https://ec.europa.eu/commission/sites/beta-political/files/mission-letter-stella-kyriakides_en.pdf

effectively, including through research and international development cooperation, as part of the Union's commitment to global health, universal health coverage and SDG 3.

1.1 Staying healthy in a rapidly changing society

People´s health and care needs are different, depending on their age, stage of life and socio-economic background.[17] Their physical and mental health and well-being can be influenced by their individual situation as well as the broader societal context they are living in. Furthermore, health education and behaviour are important factors. Currently, more than 790'000 deaths per year in Europe are due to risk factors such as smoking, drinking, physical inactivity, and obesity.[18,19] Upbringing, income, education levels, social 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 and find its way through new technological tools and societal 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.

1.2 Living and working in a health-promoting environment

The environment we live and work in has direct beneficial or negative impacts on human health and well-being. It is a major determinant of health, estimated to account for almost 20% of all deaths in Europe.[20] The factors causing these impacts on both physical and mental health are not all identified nor their effects comprehensively understood and accounted for in decision-making.[21] There are still considerable knowledge gaps in the understanding of the environmental, occupational and socio-economic risk factors for health and well-being. These risk factors include pollution, chemicals, noise, radiation, urbanisation, climate and other environmental changes, socio-economic inequalities, and changing working environments, and are influenced by lifestyle and behavioural factors. Moreover, the determinants of a health-promoting environment need further understanding and evidence.

[17] For instance, the number of Europeans over 65 with age-related impairments is expected to grow 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 body functions and capabilities.

[18] Health at a glance Europe 2018 (OECD, European Commission)

[19] 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. Obesity is one of the greatest public health challenges of the 21st century whose prevalence has tripled in many EU countries since the 1980s.

[20] WHO Europe: Environment and Health at http://www.euro.who.int/en/health-topics/environment-and-health

[21] Annually more than 400'000 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.

1.3 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. They pose a major health, societal and economic threat and burden for people. Many people are still dying prematurely and suffering from these diseases. Non-communicable diseases, including mental illnesses and neurodegenerative diseases, are responsible for up to 80% of EU health care costs.[22] 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. Infectious diseases, including antimicrobial resistant (AMR) infections, remain a major threat to health in the EU and global health security. AMR deaths could exceed 10 million per year worldwide according to some predictions.[23]

1.4 Ensuring access to innovative, sustainable and high-quality health care

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 needs to be adapted and reformed to cope with societal trends and changes that include demographic, epidemiological, technological, environmental and socio-economic transitions.

1.5 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 and care sector. It can provide better and more cost-efficient solutions with high impact and can be tailored to the specific health and care needs of patients for improving their quality of life. However, novel therapies, technologies and approaches face specific barriers and hurdles in implementation and scale-up before reaching health care systems and patients, including societal issues such as technology acceptance or public outreach. In addition, several emerging disruptive technologies and the availability of vast amounts of data and digitalisation offer big opportunities for transforming health and care and promoting health and well-being of citizens. Unlocking these opportunities depends on the capacity to collect, combine and make sense out of vast amounts of data, on the availability of appropriate regulatory frameworks and data infrastructures that will both safeguard the rights of the individual and of society, and stimulate innovation to develop impactful solutions. European Health Data Space will promote health-data exchange and support research on new preventive strategies, as well as on treatments, medicines, medical devices and outcomes. Due consideration of aspects of safety, effectiveness, appropriateness, accessibility, comparative value-added and fiscal sustainability as well as issues of ethical, legal and regulatory nature will be crucial in order to translate these innovations into health policies, health and care systems, and clinical practice.

1.6 Maintaining an innovative, sustainable and globally competitive health industry

The health industry is a key driver for growth and contributes to employment through high-value jobs and a positive trade balance, and has the capacity to provide health technologies[24] to the benefit of patients and providers of health and care services in Europe and worldwide. The development of novel 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

[22] 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. Every day, 22'500 people die 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).

[23] AMR is estimated to be responsible for 25,000 deaths per year in the EU alone and 700,000 deaths per year globally. It has been estimated that AMR might cause more deaths than cancer by 2050.

[24] 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.

difficulties to access the necessary investments, new markets and value-chains, or in setting-up partnerships and create alliances. Because health innovation impact healthcare, patients and society, the relevant value chains involve a broader variety of key players from supply, demand and regulatory side. A comprehensive approach relies therefore on cooperation and capacity building within a value ecosystem.

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.[25]

The EU is strongly committed to the 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. 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 research and innovation at the national, European and international level.

Cluster 1 will also be instrumental in supporting research and innovation actions contributing to initiatives that are part of the political guidelines and mission letters of the Commission 2019-2024, notably to a European Green Deal, to a an economy that works for people, to Europe fit for the digital age, and a stronger Europe in the world, and in particular to:

- implementing the European One Health Action Plan against Antimicrobial Resistance and combatting vaccination hesitancy;
- contributing to a Europe's Beating Cancer Plan to support EU member states in improving cancer control and care;
- creating European Health Data Space to promote health-data exchange and support research;
- developing a new Comprehensive Strategy on Africa.

3. Targeted Impacts

Research and innovation supported under Cluster 1 aims to advance knowledge, build capacities as well as design, develop and demonstrate innovative solutions that will improve the health and well-being of people and support the transformation of health care systems. However, it will also 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

[25] 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'

implement the recommendations and innovative solutions developed through research and innovation to achieve desired impacts. To maximise the benefits of EU investments and support the EU in achieving its goals, the cluster health will promote and foster synergies with public health policies at national and regional level, with other EU programmes and policies, as well as with health-related European infrastructures. Research and innovation activities under this Cluster shall target and contribute to the following interlinked, long-term impacts:

3.1 Staying healthy in a rapidly changing society

Research and innovation aims at supporting citizens in pursuing healthy and active lives (increased 'Healthy Life Years' HLY[26]) by providing suitable and tailor-made solutions, including for people with specific needs, such as rehabilitation. Targeted impacts are:

1. Pregnancy and birth is safer, maternal mortality is reduced[27], preventable deaths of new-borns and children under 5 years of age[28] are suppressed, and the physical and mental health and well-being of children and adolescents (and their families) is improved.[29,30,31]

2. Citizens adopt healthier lifestyles and behaviours, make healthier choices (such as healthier food choices) and maintain longer a healthy, independent and active life with a reduced disease burden, including at old ages or in other vulnerable stages of life. They are able and empowered to manage better their own physical and mental health and well-being, monitor their health, and interact with their doctors and health care providers.[32]

3. Citizens´ trust in knowledge-based health interventions and in guidance from health authorities is strengthened, including through improved health literacy (including in young age), resulting in increased engagement in and adherence to effective strategies for health promotion, diseases prevention and treatment, including increased vaccination rates[33] and patient safety.

4. Citizens are protected from health risks due to misinformation[34], manipulation and fraud, including the sale, purchase and use of substandard, falsified[35] or inappropriate medicines.

5. Health policies and actions for health promotion and disease prevention are knowledge-based, targeted to citizens' needs, and designed to reduce health inequalities.

3.2 Living and working in a health-promoting environment

Research and innovation aims at protecting citizens' health from negative impacts resulting from environmental and occupational risk factors. Targeted impacts are:

1. Citizens' health and well-being is protected and promoted, and premature deaths, diseases and inequalities related to environmental pollution and degradation are prevented. [36,37] In

[26] 'Healthy Life Years' (HLY), also called 'disability-free life expectancy' (DFLE), is a statistical indicator compiled separately for men and women, at birth and at ages 50 and 65, and is defined as the number of years that a person is expected to continue to live in a healthy condition. It is based on age-specific prevalence (proportions) of the population in healthy and unhealthy condition and age-specific mortality information. A healthy condition is defined as one without limitation in functioning and without disability.

[27] SDG3 target 3.1, 3.2, 3.7

[28] SDG 3 target 3.2

[29]SDG 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

[30] EU Action Plan on Childhood Obesity 2014-2020,

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

[32] Commission Communication on the digital transformation of health and care.

[33] Council recommendation on strengthened cooperation against vaccine preventable diseases

[34] Commission Communication on Tackling online disinformation – a European approach

[35] Directive on Falsified Medicines

[36] Decision No 1386/2013/EU on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet', http://ec.europa.eu/environment/action-programme/.

particular, the health threat and burden resulting from hazardous chemicals and air, water and soil pollution and contamination is reduced, including at the workplace, such that the related number of deaths and illnesses is substantially reduced by 2030.[38]

2. The adaptive capacity and resilience of populations and health systems in the EU to climate and environmental change-related health risks is strengthened[39]

3. The upstream determinants of disease - related to choices in energy generation, agricultural practices, industrial production, land use planning, built environment and construction - are known, understood and reduced.[40]

4. Living and working environments in European cities and regions are healthier, more inclusive, safer, resilient and sustainable. [41]

5. Policy-makers and regulators are aware and better informed about environmental, socio-economic and occupational risk factors as well as health-promoting factors, including the combination of factors, for health and well-being across society.[42] Accordingly, knowledge-based policies at EU and global level better protect and promote citizens' health and well-being, and reduce health inequalities.[43]

6. Citizens understand better complex environment and health issues, and effective measures to address them and support related policies and regulations.[44]

3.3 Tackling diseases and reducing disease burden

Research and innovation aims at decreasing the burden of diseases on citizens and health care systems. Targeted impacts are:

1. Health burden of diseases in the EU and worldwide is reduced through effective disease management, including through the development and integration of innovative diagnostic and therapeutic approaches, personalised medicine approaches, digital and other people-centred solutions for health and care. In particular, patients are diagnosed early and accurately and receive effective, cost-efficient and affordable treatment, including patients with a rare disease, due to effective translation of research results into new diagnostic tools and therapies.

2. Premature mortality from non-communicable diseases is reduced by one third (by 2030), mental health and well-being is promoted, and the voluntary targets of the WHO Global Action Plan for the Prevention and Control of NCDs 2013-2020 are attained (by 2025), with an immediate impact on the related disease burden (DALYs).[45,46, 47]

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[37] 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

[38] SDG 3 target 3.9

[39] 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

[40] WHO global strategy on health, environment and climate change. https://www.who.int/phe/publications/global-strategy/en/

[41] 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

[42] 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

[43] 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.

[44] 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

[45] WHO Global Action Plan for the Prevention and Control of NCDs 2013-2020 (resolution WHA66.10). https://www.who.int/nmh/events/ncd_action_plan/en/

3. Health care systems benefit from strengthened research and innovation expertise, human capacities and know-how for combatting communicable and non-communicable diseases, including through international cooperation. In particular, they are better prepared to respond rapidly and effectively to health emergencies and are able to prevent and manage communicable diseases transmissions epidemics, including within healthcare settings.

4. Citizens benefit from reduced (cross-border) health threat of epidemics and AMR pathogens, in the EU and worldwide.[48,49] In particular, the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases are contained and hepatitis, water-borne diseases and other communicable diseases are being combated.[50]

5. Patients and citizens are knowledgeable of disease threats, involved and empowered to make and shape decisions for their health, and better adhere to knowledge-based disease management strategies and policies (especially for controlling outbreaks and emergencies).

6. The EU benefits from high visibility, leadership and standing in international fora on global health and global health security, especially in partnership with Africa.

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

Research and innovation aims at supporting health care systems in their transformation to ensure fair access to sustainable health care services of high quality for all citizens. Targeted impacts are:

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, by shifting from hospital-centred to community-based, people-centred and integrated health care structures and successfully embedding technological innovations that meet public health needs, while patient safety and quality of services is increased.

2. Health care providers are trained and equipped with the skills and competences suited for the future needs of health care systems that are modernised, digitally transformed and equipped with innovative tools, technologies and digital solutions for health and care. They save time and resources by integrating and applying innovative technologies, which better involve patients in their own care, by reorganising workflows and redistributing tasks and responsibilities throughout the health care system, and by monitoring and analysing corresponding health and care activities.

3. Citizens play a key role in managing their own health and care, informal carers (i.e. unpaid carers) are fully supported (e.g. by preventing overburdening and economic stress) and specific needs of more vulnerable groups are recognised and addressed. They benefit from improved access to health care services, including financial risk protection, timely access to quality essential health care services, including safe, effective, and affordable essential medicines and vaccines.[51]

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[46] Including for instance the following voluntary targets (against the 2010 baseline): 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.

[47] Disability-adjusted life year (DALY) is a quantitative indicator of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.

[48] WHO global action plan on antimicrobial resistance, 2015.

[49] EU One Health Action Plan against AMR, 2017.

[50] SDG 3 target 3.3

[51] SDG 3 target 3.8

4. Health policy and systems adopt a holistic approach (individuals, communities, organisations, society) for the evaluation of health outcomes and value of public health interventions, the organisation of health and care, and decision-making.

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

Research and innovation aims at supporting the integration and deployment of innovation in health care systems. Targeted impacts are:

1. Europe's scientific and technological expertise and know-how, its capabilities for innovation in new tools, technologies and digital solutions, and its ability to take-up, scale-up and integrate innovation in health and care is world-class.

2. Researchers, innovators and health care providers use health data and Artificial Intelligence (AI) supported decision-making in a secure and ethical manner, respecting individual integrity and underpinned with public acceptance and trust.

3. Better informed policies and tailored legal, regulatory and ethical frameworks for the development of innovative health technologies, and better understanding of the societal impacts and acceptance of innovative health technologies and the digital transformation of health and care.

4. Citizens benefit from targeted and faster research resulting in safer, more efficient, cost-effective and affordable tools, technologies and digital solutions for improved (personalised) disease prevention, diagnosis, treatment and monitoring for better patient outcome and well-being, in particular through increasingly shared health resources (interoperable data, infrastructure, expertise, citizen/patient driven co-creation). [52]

5. Citizens trust and support the opportunities offered by innovation for health and care, are involved in their design and take part in informed decision-making, based on expected health outcomes and potential risks involved.

3.6 Maintaining an innovative, sustainable and globally competitive health industry

Research and innovation aims at supporting the health industry in the development of novel health technologies addressing public health needs and market opportunities. Targeted impacts are:

1. Health industry in the EU is more competitive, sustainable and growing, providing high-value jobs and contributing to economic growth, in particular SMEs, by tapping into new markets and providing European leadership in breakthrough health technologies and innovations.

2. Health industry in the EU, in particular SMEs, gain the ability to grow and reach a critical mass to develop innovative products and services and to tap into international value chains and international markets.

3. Citizens, health care providers and health systems benefit from a swift uptake of innovative health technologies and services offering significant improvements in health outcomes, while health industry in the EU benefit from decreased time-to-market.

4. 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, health care providers, health authorities and regulators ensuring suitability and acceptance of solutions.

[52] Commission Communication on the digital transformation of health and care.

5. Health security in the EU benefits from reliable access to key manufacturing capacity, including timely provision of essential medical supplies of particularly complex or critical supply and distribution chains, such as regards vaccines or medical radioisotopes.

6. European standards, including for operations involving health data, ensure patient safety and quality of healthcare services as well as effectiveness and interoperability of health innovation and productivity of innovators.

4. Key Research and Innovation Orientations

Research and innovation supported under Cluster 1 *Health* should mobilise researchers from academic institutions, research organisations, small and medium enterprises, and large companies, as well as citizens and patients, patients associations, providers of health and care services and regulatory instances, in order to tackle the six health-related challenges and deliver on the targeted impacts. Synergies with the Euratom Research and Training Programme[53] will be explored as regards innovation on medical applications of ionising radiation, including improvements in the quality and safety of such applications. Moreover, pan-European research infrastructures[54] will be harnessed, including those identified by the European Strategy Forum for Research Infrastructures (ESFRI) and those established under the European Research Infrastructures Consortium (ERIC) regulation[55], to strengthen the productivity of European health research and innovation and to support the development of effective, fiscally and environmentally sustainable solutions while promoting access to health innovation. In order to achieve the greatest impact and benefits for the health and well-being of its population, it is also essential that the EU continues its efforts in cross-border cooperation, coordination and alignment. This includes European Partnerships, major international initiatives and established multilateral networks, e.g., in the area of infectious diseases, non-communicable diseases, rare diseases, brain research, and -omics[56] and environment and health. International cooperation and partnerships with third countries and other international partners are key for tapping the best expertise and know-how available worldwide, for leveraging a critical scale of resources, and for tackling global health challenges. Infectious diseases outbreaks and the spread of antimicrobial resistance (AMR) do not follow geographical borders, environmental factors in an urban or rural context create similar exposure and occurrences in different regions, and demographic changes due to societal segregation (urbanisation) and ageing as well as the challenges of data are not European challenges only. It will also be important that the cluster health can react swiftly and decisively to Public Health Emergencies of International Concern (PHEIC) declared by WHO and support urgently needed research. Seeking complementarities and synergies with the EU's external actions, development cooperation and trade policies will not only reinforce the links between research and implementation and support evidence-based policy-making but in particular amplify the uptake and deployment of research and innovation results and solutions and thus the impact of EU investments, including with regard to the EU's commitment to the United Nation's 2030 Agenda for Sustainable Development, notably SDG 3, and those in the context of other UN organisations and international initiatives, including the global strategies and plans of action of the World Health Organization (WHO).

The following sections describe the most important short to medium-term outcomes and impacts that contribute to achieving the targeted long-term impacts outlined in the previous chapter. In

[53] COM/2018/437 final - 2018/0226 (NLE), Proposal for a Council Regulation establishing the Research and Training Programme of the European Atomic Energy Community for the period 2021-2025 complementing Horizon Europe – the Framework Programme for Research and Innovation

[54] https://www.esfri.eu/

[55] Such as : European Life-Science Infrastructure for Biological Information (ELIXIR) https://elixir-europe.org/, European Clinical Research Infrastructure Network (ECRIN) https://www.ecrin.org/; European infrastructure for translational medicine (EATRIS) https://eatris.eu/; Survey of Health, Ageing and Retirement in Europe (SHARE) http://www.share-project.org/; European research infrastructure for biobanking (BBMRI) http://www.bbmri-eric.eu/; European Social Survey (ESS) http://www.europeansocialsurvey.org/.

[56] '-omics' aims at the collective characterization and quantification of pools of biological molecules that translate into the structure, function, and dynamics of an organism or organisms and includes the genome itself (genomic), transcription products (transcriptomic), protein products (proteomic) and metabolic products (metabolomic).

other words, the following sections outline what research and innovation interventions and results are needed to tackle the health-related challenges. To enhance the societal relevance and impact of the knowledge, technologies and innovations developed under Cluster 1 *Health*, sex-specific and/or gender-specific approaches may be required since "every cell is sexed, every person is gendered"[57]. This will contribute to develop new insights, new products, new services or new markets tailored to specific sex/gender-specific needs, behaviours and attitudes.

4.1 Staying healthy in a rapidly changing society

Research and innovation can provide a better understanding of specific health and care needs throughout the life course, including age-specific and sex/gender-specific needs, and develop more effective solutions for health promotion and disease prevention, including for needs related to chronic health conditions, physical and mental disabilities, or age-related impairments. Research and innovation can help people, as well as communities, in developing innovative services, policies, guidelines 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 orientation will support activities aiming at:

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

Intervention areas:[58] This challenge requires research and innovation actions under several intervention areas (IA) of cluster 1 but the centre of gravity lies with IA 1.2.1. 'Health throughout the Life Course'. It is closely linked to IA 1.2.2 'Environmental and Social Health Determinants'.

Cross-cluster issues: Synergies with other clusters could be explored through broad cross-sectoral collaboration. For example with cluster 2 'Culture, creativity and inclusive societies' on health inequalities, on other inequalities affecting health, or on end users' engagement; ii) with cluster 6 'Food, Bioeconomy Natural Resources, Agriculture and Environment' on the role 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 and consumer habits). Other possible synergies could be explored by cooperating on digital tools, telemedicine or smart homes with cluster 4 'Digital, Industry and Space' or with cluster 5 'Climate, Energy and Mobility' on urban health or on mitigating the impact of road traffic accidents and related injuries.

[57] International Conference on 'Innovations in Gender, Sex, and Health Research: Every Cell is Sexed, Every Person is Gendered', Toronto, 22-23 Nov 2010.

[58] Intervention areas are set in the proposed Specific Programme of Horizon Europe.

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

Research and innovation 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 European Green Deal, the future 8th Environment Action Programme, the EU Strategic Framework on Health and Safety at Work[59] and the European Environment and Health Process (EHP)[60]. The outcome will also contribute to the development of new and improved health interventions and technologies. In order to achieve sustainable impacts, research and innovation must provide solid evidence and stimulate its uptake into a large number of environmental, occupational, social, economic, fiscal and health 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, security, urban planning, social inclusion and gender 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 research and innovation orientation will support activities aiming at:

1. Collection, combination and analysis of environmental, occupational and human health-related data, taking advantage of the exposome[61] 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 socio-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.

Intervention areas:[62] This challenge involves research and innovation actions under several intervention areas (IA) of cluster 1 and other clusters, but the centre of gravity lies with IA 1.2.2. 'Environmental and Social Health Determinants'. It is closely linked to IA 1.2.1 'Health throughout the Life Course'.

Cross-cluster issues: Synergies with other clusters could be explored through broad cross-sectoral collaboration, for example with cluster 6 'Food, Bioeconomy Natural Resources, Agriculture and Environment' on human biomonitoring, on healthy ecosystems and human habitats (incl. nature-based solutions for health and well-being), or on the sustainable management of clean water, soil and air. Other possible synergies could be explored by cooperating i) with cluster 4 'Digital, Industry and Space' on health-related space research and innovation for location-based services, geo-observation and monitoring (e.g. of pollution), ii) with cluster 5 'Climate, Energy and Mobility' on the surveillance, prediction and mitigation of the health impact of climate change, on the health

[59] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0332
[60] http://www.euro.who.int/__data/assets/pdf_file/0009/341946/Annex2_20June.pdf?ua=1
[61] The concept of the exposome refers to the totality of environmental exposures (diet, lifestyle, occupational and environmental factors) from conception onwards, including its external and internal components.
[62] Intervention areas are set in the proposed Specific Programme of Horizon Europe.

impact of transport-related environmental pollution (such as air and noise pollution), on transport and mobility related risks on health, or on concepts/technologies for smart and healthy homes, rural areas and cities, and iii) with cluster 4, 5 and 6 on health impact assessment, e.g. the impacts on health and well-being of infrastructure, urban planning, transport, technologies, chemicals and other substances (incl. pollution), or iv) with clusters 5 and 6 on preventable environmental causes of diseases.

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).

European Partnerships: *"European Partnership on Chemical Risk Assessment":* A partnership on chemicals risk assessment would be launched in 2022 to support the EU/national chemical risk assessment and management authorities by providing new evidence and methodologies and stimulate their uptake in regulatory processes. The joint research and innovation programme would target established chemical regulatory processes and facilitate their adaptation to and preparedness for persistent or emerging challenges. It would aim to strengthen European capacities in the areas of: human biomonitoring; environmental and food monitoring; toxicology and hazard assessments; exposure assessment; emerging chemicals; chemical mixtures; validation, standardisation and reference materials; risk assessment methodologies; data management and analysis; risk communication, dissemination and training; priority setting and sustainability. The partnership would not replace already existing mandatory reporting or monitoring schemes enshrined in EU regulations, but enrich them with new knowledge and tools where necessary. The partnership would contribute to the sustainability of the human biomonitoring platform developed by HBM4EU (2017-2021), by incorporating it into a wider chemical risk assessment initiative as recommended during the 2018 Human Biomonitoring conference. In fine, the partnership would provide an EU-wide research platform complementing the EU chemical regulatory system, thereby strengthening the EU-MS collaborations for chemical risk assessment and management.

4.3 Tackling diseases and reducing disease burden

There is an urgent need for research and innovation on new prevention, diagnostics, vaccines, therapies, alternatives to antibiotics, as well as to improve existing prevention strategies to create tangible impacts, taking into account sex/gender-related issues. This 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 research and innovation cooperation. The continuation of international partnerships and cooperation with international organisations is particularly needed to combat infectious diseases, including antimicrobial resistances, to respond to major unmet needs for global health security, including the global burden of non-communicable diseases, and to strengthen patient safety.

This research and innovation orientation will support activities aiming at:

1. Better understanding of diseases, their drivers and consequences, including pain and the causative links between health determinants 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, detection, treatment and crisis management of infectious disease threats.

4. Innovative health technologies developed and tested in clinical practice, including personalised medicine approaches and use of digital tools to optimise clinical workflows.

5. New and advanced 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/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).

Intervention areas:[63] This challenge requires research and innovation actions under several intervention areas (IA) in cluster 1 but the centre of gravity lies with IAs 1.2.3. 'Non-Communicable and Rare Diseases' and 1.2.4. 'Infectious Diseases'. It is closely linked to IA 1.2.2 'Environmental and Social Health Determinants'.

Cross-cluster issues: Synergies with other clusters could be explored through broad cross-sectoral collaboration, for example with cluster 3 "Civil security for 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, bioeconomy, natural resources, agriculture and environment" on health security and AMR (one-health: human/animal/plant/soil/water health).

International cooperation: Effective international cooperation is essential to reduce disease burden and to protect people against cross-border health threats including the rise and spread of AMR and (re)emerging epidemics. The EU should continue its efforts to initiate and participate in cross-border coordination and integration of research and innovation. To address these challenges of global dimension, it will require international cooperation to pool the best expertise and know-how available worldwide, enable a better alignment with actions in the rest of the world, and contribute to the achievement of SDG 3 'Healthy lives and well-being for all'. This includes international collaboration with major EU and global initiatives in the area of infectious diseases (Global Research Collaboration for Infectious Disease Preparedness, GloPID-R), non-communicable diseases (Global Alliance for Chronic Diseases, GACD), rare diseases (International Rare Diseases Research Consortium, IRDiRC), brain research (International Traumatic Brain Injury Research, InTBiR), personalised medicine (International Consortium for Personalised Medicine, ICPerMed), and -omics[64] (e.g. the International Human Epigenome Consortium, IHEC, the 1 Million Genomes Initiative), and global health (World Health Organisation and other UN agencies)

European Partnerships:
i) *"EU-Africa global health partnership to tackle infectious diseases"*: This research and innovation partnership would aim to increase global health security in sub-Saharan Africa (SSA) and Europe, by accelerating the clinical development of effective, safe, accessible, suitable and affordable health technologies as well as health systems interventions for infectious diseases in partnership with Africa and international funders. It would also support implementation research and health systems research for the uptake of new, improved or existing medical interventions. This partnership would be the successor initiative of the EDCTP2 partnership programme and be launched in 2021. It could be established as an institutionalised partnership based on Article 185/187 TFEU.

ii) *"Rare Diseases":* This research and innovation partnership would aim to improve the lives of rare diseases patients. It would built on the results and experiences the ERA-Net E-Rare which was continued in the frame of the European Joint Programme on Rare Diseases (EJP RD). The EJP RD has been launched in December 2018 to further help in coordinating the research efforts of European, Associated and non-European countries in the field of rare diseases and implement the objectives of the International Rare Disease Research Consortium (IRDiRC). The proposed

[63] Intervention areas are set in the proposed Specific Programme of Horizon Europe.
[64] '-omics' aims at the collective characterization and quantification of pools of biological molecules that translate into the structure, function, and dynamics of an organism or organisms and includes the genome itself (genomic), transcription products (transcriptomic), protein products (proteomic) and metabolic products (metabolomic).

research and innovation partnership would be established as co-funded partnership programme, starting in 2024.

iii) *"Fostering an ERA for Health Research":* Several existing Horizon2020-funded partnerships involve the very same health research and innovation funders but are simply focused on different thematic priority areas. The proposed research and innovation partnerships would aim to establish a flexible and more effective coordination between programme owners (typically ministries) and programme funders (typically funding agencies) of the numerous networks established in the European Research Area (ERA) for Health and Well-being. It would focus on establishing a strategic research agenda and joint funding strategy between major European funders, public and private, on translational health research and innovation, and would be established as a co-funded partnership, starting in 2023/2024.

iv) "*One Health AMR*": At the highest political levels antimicrobial resistance (AMR) is recognised as a major threat to the health of our citizens and our society. The EU One Health Action Plan against AMR provides the framework within which action should be taken against this threat. However, the AMR research landscape is currently fragmented addressing human health, animal health, food safety and environment in silos. The proposed research partnership aims to bring together the many aspects of AMR to overcome this fragmentation, and integrate the various different research fields. It will engage public health, animal health and environment research funders from EU member states as main partners to support the implementation and financing of a strategic research agenda as part of a joint research programme. This candidate partnership builds on the ERA-Net EXEDRA (ends in 2020) that supports the JPIAMR and on the One Health EJP (ends in December 2022). It would be established as co-funded partnership, starting in 2023/2024.

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

Research and innovation 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, and patient empowerment). In addition, research and innovation can provide decision-makers with new evidence, methods and tools to successfully implement those innovative solutions into their 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.

<u>This research and innovation orientation will support activities aiming at:</u>

1. Innovative solutions to support modernisation of health care systems (e.g. organisational models; innovative health service delivery models; integrated care models; long-term care; digitalised services; personalised approaches; financing models, including financing of health care systems; remuneration models; incentive mechanisms; new payment/ reimbursement models of health technologies[65]; accelerated access models in case of health emergencies; human resources planning, education and training, incl. on digital skills and health data management).

2. Methods, tools and demonstrated pilots for uptake and scale-up of innovation in health systems (e.g. technological and 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 care 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, and to improve citizen empowerment, access of citizens to their own health data, health literacy, self-care, informal care, and community care.

[65] 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.

5. Successful models, strategies and solutions increasing patient safety by preventing and reducing risks for patients during the delivery of health care services.

6. 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 care 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.

7. 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, including reinvestment from low to high value care for patients.

8. Methods to assess performance and efficiency of healthcare organisations and health care systems based on outcomes that matter for patients and carers, aiming at reducing health inequality and allowing for international comparability.

9. Identification of factors accounting for health care systems resilience in absorbing the impact of crises, such as the expected dementia raise, and accommodating disruptive innovation.

Intervention areas:[66] All research and innovation areas of cluster 1 are concerned but the centre of gravity lies with IA 1.2.6 'Health Care Systems'. It is closely linked to IA 1.2.1 'Health throughout the Life Course' as well as IA 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 2 "Culture, Creativity and Inclusive 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, or with cluster 3 "Civil security for society" on security of health care infrastructures, incl. digital health infrastructures, or health systems preparedness and response to natural disasters and emergencies. 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 health promotion and care is key in this area of research. Research on health care systems will benefit from cooperation with international actors: such as the World Health Organization's Science Division and national 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). Universal health coverage is also an important area of international development cooperation, in particular as regards sexual and reproductive health and rights.

European Partnerships:
i) *"Health and Care Systems Transformation".* This research and innovation partnership with health and care systems owners/organisers and the respective research and innovation funders would aim at boosting research for policy making, uptake and scale-up of innovative solutions to accelerate transformation of national/regional health and care systems. Specific objectives would be to provide evidence for innovative solutions that support cost-effective and fiscally sustainable health and care policies, to build knowledge on the conditions for transferability and up-scaling of innovative solutions across and within EU countries, to develop and test a mechanism to support diffusion of innovative solutions, to unleash unmet needs of citizens and health and care systems and to establish an research and innovation platform that brings together the different actors as well as health data across health and care systems to enable data-driven policy and exchange. The partnership would build on the strategic research agenda developed by the Horizon 2020-funded support action TO-REACH, will draw on the expertise and experiences from the Member States and

[66] Intervention areas are set in the proposed Specific Programme of Horizon Europe.

network of regions involved in the European Innovation Partnership on Active and Healthy Ageing (EIP-AHA), the Second 'Active and Assisted Living' programme (AAL2), the InfAct Joint Action, the MYBL JPI and work in synergy with the EIT KIC-Health. A strong synergistic link will be created with the European partnership on 'Innovative Health Initiative'. It would be established as co-funded partnership, starting in 2021.

ii) *"Personalised Medicine":* This research and innovation partnership would align priority setting and funding for research projects in the area of personalised medicine between the EU Member States and regions, associated countries and international partner countries. It would be the successor initiative of the Horzion2020-funded ERA-PerMed partnership and also build on the Horzion2020-funded actions in support of the International Consortium for Personalised Medicine (ICPerMed) led by several EU Member States. Based on the on the results and experiences with ERA-PerMed, the proposed partnership would continue to align national research strategies, promote research and innovation excellence, reinforce the competitiveness of European players in personalised medicine and enhance the European collaboration with non-EU countries, including by supporting collaborative innovative research projects through joint transnational calls for proposals. It would be established as co-funded or co-programmed partnership programme, starting in 2023.

Innovation Procurement: Innovation procurement is a mean to drive innovation from the demand side. Procurers (e.g. health care providers) are potential buyers of innovative solutions to public health interest needs that are not yet available, or in insufficient quantity, on the market. Innovation procurements can initiate innovation through the purchase of R&D services, when market solutions are missing, or boost the marketing of existing solutions for early adopters. Innovation procurement can then open market opportunities for European companies, including SMEs.

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

Research and innovation 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, inter-operability, appropriateness, accessibility, comparative value-added, affordability and sustainability (environmental, fiscal, socio-economic) and issues of ethical, societal, regulatory and legal nature will be crucial in order to boost the acceptability of these novelties and to translate these innovations into health policies, health and care systems, and clinical practice responsibly. Moreover, to provide high-quality healthcare and reduce health inequalities, end users' engagement in multidisciplinary, cross-sectorial cooperation with key stakeholders (patients, health care providers, researchers, regulatory bodies, policy-makers, funders) could help addressing specific unmet needs for health tools, technologies and digital solutions with limited commercial interest but also designing and developing suitable health products and services tailored to specific needs related to sex/gender or other aspects. 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 health care and for supporting health care systems in their clinical, organisational and logistical functions.

This research and innovation orientation will support activities aiming at:

1. New tools and technologies for biomedical research, prevention, diagnosis and therapy of diseases and tools for monitoring diseases as well as treatment progression are designed, developed, tested or validated for the benefit of patients and the health and care systems. These solutions can include a variety of technologies and approaches such as nano medicines, advanced therapies, biomaterials, medical devices, hybrid technologies, digital solutions, Artificial Intelligence applications, robotics, -omics[67] and other data-driven interventions and procedures.

[67] '-omics' aims at the collective characterization and quantification of pools of biological molecules that translate into the structure, function, and dynamics of an organism or organisms and includes the genome itself (genomic), transcription products (transcriptomic), protein products (proteomic) and metabolic products (metabolomic).

2. Health data accessibility and interoperability across the EU, including the free flow and secure exchange of health data, leaning on existing research infrastructures[68] as well as the creation of a European Health Data Space to promote health-data exchange and support research.

3. Improved risk-benefit ratio of the developed innovative tools, technologies and approaches owing to powerful digital solutions using and processing big data for better detection, diagnosis and monitoring of disease, including real-world data, for efficient value assessment.

4. Efficient up-scaling and production systems, including bioprinting, additive manufacturing and other advanced manufacturing techniques, enabling targeted and personalized health interventions.

5. Improved health technologies and interventions based on digital solutions, which support timely health information and secure use of health data.

6. New data-driven approaches, computer models and -simulations and other digital solutions are developed, translated and optimised for the prevention, health care and person-centred care, including smart data infrastructures and AI-based data analytics.

Intervention areas:[69] This challenge will benefit from research and innovation actions under several intervention areas (IA) of cluster 1 but the centre of gravity lies with IA 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, in particular with cluster 4 "Digital, Industry and Space" on: digitalisation of the health sector, incl. health technologies, medical devices and key enabling technologies; assisted, autonomous, independent and empowered living; smart homes; decision support systems; health impact assessment (e.g. related to consumer products, working place innovation). Moreover, research and innovation actions under cluster health may be inspired by research achievements under Pillar I (Open Science) or may benefit from follow-on support under Pillar III (Open Innovation).

Innovation Procurement: Innovation procurement is a means to drive innovation from the demand side. Procurers are potential buyers of innovative solutions to public interest needs that are not yet available, or in insufficient quantity, on the market. Public procurements can initiate innovation through the purchase of R&D services, when market solutions are missing, or boost the marketing of existing solutions for early adopters. Innovation procurement can then open market opportunities for European companies, including SMEs.

4.6 Maintaining an innovative, sustainable and globally competitive health industry

There is a convergence and a need for cross-sectorial research and innovation (integrating medical technologies, pharmaceuticals, biotechnologies, digital health and eHealth technologies) 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 sustainability (environmental, fiscal, socio-economic) while fostering access and reducing health inequalities.

The health sector is subjected to strict regulatory requirements that impose the demonstration of clinical benefit(s) and safety. This means additional development steps, uncertainties and a longer time to market. Support to studies for health assessment procedures, clinical performance demonstration, quality assurance schemes and standardisation are therefore important elements.

This research and innovation orientation will support activities aiming at:

[68] Such as the European Life-Science Infrastructure for Biological Information (ELIXIR: https://elixir-europe.org/), identified by the European Strategy Forum for Research Infrastructures (ESFRI).

[69] Intervention areas are set in the proposed Specific Programme of Horizon Europe.

1. Efficient innovation management strategies, including intellectual property, to translate breakthrough technologies into health care applications.

2. Efficient collaboration with regulatory authorities and health care providers for an optimal time to patient access.

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 impact and integration into regulatory frameworks, and for allowing swift access by health care providers, patients and healthy citizens.

4. Regulatory authorities supported with better methodologies and interdisciplinary approaches to assess new health technologies and interventions.

5. New European standards and quality assurance schemes developed for submission to standardisation bodies and implementation by stakeholders that, e.g., support a fast, reliable and secure handling of health data, health products or health services.

6. Safe and clinically validated tools, technologies and services developed and delivered by European health industry that meet the needs of citizens, patients, health care providers and systems.

7. Greener pharmaceuticals and health technologies.

Intervention areas: All research and innovation areas of cluster 1 are concerned but the centre of gravity lies with IA 1.2.5. 'Tools, Technologies and Digital Solutions for Health and Cre', while it is closely linked to IA 1.2.6 'Health Care Systems'.

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 research and innovation infrastructures (pilot plants, testing and simulation facilities, open innovation hubs); additive manufacturing (3D/4D printing) and other production technologies (incl. bio manufacturing); safe, smart and sustainable materials. Synergies could also be explored with Pillar III, "Open Innovation", in particular the scheme of the EIC that supports breakthrough and risky innovations.

European Partnerships:
"Innovative Health Initiative": This partnership would provide a cross-sectoral collaborative platform bringing the pharmaceuticals, diagnostics, medical devices, imaging and digital industries together with public sector and other relevant stakeholders. It would contribute significantly to "*Enabling the digital transformation of health and care in the Digital Single market*" by supporting precompetitive research and innovation in areas of unmet public health and accelerating the development of people-centred health care innovations that can be taken up in health and care systems. It intends to overcome barriers that prevent exploiting the full potential of digitalisation and data exchange, through standards, methods and tools for interconnectivity and interoperability as well as to deliver tools, data, platforms, technologies and processes that enable the delivery of innovative health products and services to predict, prevent, intercept, diagnose and manage diseases more efficiently, that meet the needs of the end users and payers. A strong synergistic link will be created with the European Partnership on 'Large-scale innovation and transformation of health systems in a digital and ageing society', thereby warranting the usefulness, transferability and the potential uptake of the developed health solutions into public health systems. This partnership would be the successor initiative of the IMI2 partnership programme as a possible institutionalised Partnership based on Article 187 TFEU. It will be launched in 2021.

Innovation Procurement: Innovation procurement is a mean to drive innovation from the demand side. Procurers are potential buyers of innovative solutions to public interest needs that are not yet available, or in insufficient quantity, on the market. Public procurements can initiate innovation through the purchase of R&D services, when market solutions are missing, or boost the marketing of existing solutions for early adopters. Innovation procurement can then open market opportunities for European companies, including SMEs.

5. International Cooperation

The EU is a major leader in research and innovation for developing health technologies, improving health services or adapting health systems that promote health and well-being and prevent, treat and cure diseases in Europe and worldwide. In order to maintain and extend its leadership role, international cooperation and partnerships with third countries and other international partners are key for tapping the best expertise and know-how available worldwide, for leveraging a critical scale of resources, and for tackling global societal challenges. Infectious diseases outbreaks and the spread of antimicrobial resistance (AMR) do not follow geographical borders, environmental factors in an urban or rural context create similar exposure and experiences in different regions and the burden of the ageing society as well as the challenges of treating health care data are not European challenges only. Horizon Europe's cluster health will remain an essential vehicle to realise and contribute to the EU's international commitments on global health, notably the health-related SDG 3, including its targets on global maternal, new-born and child mortality, its pollution-related morbidity and mortality targets, as well as the objectives and targets of WHO action plans and programmes of action. It will also be important that the cluster health can react swiftly and decisively to Public Health Emergencies of International Concern (PHEIC) declared by WHO and support urgently needed research. Seeking complementarities and synergies with the EU's external cooperation policies and programmes will not only reinforce the links between research and implementation and support evidence-based policy-making but in particular amplify the uptake and deployment of research and innovation results and solutions and thus the impact of EU investments. Geographic and thematic considerations will be key for setting priorities in promoting cooperation between research and innovation institutions in MS/AC with those in third countries, building research and innovation capacities, identifying market access opportunities, shortening innovation cycles, or contributing to international commitments in global fora or in a bilateral context, in particular with regard to the EU-Africa partnership. For cooperation with countries of high S&T capacities important perspectives are the opportunities of data-driven innovation and digitalisation of health and care, need for jointly tackling global health challenges, and building international value chains in delivering new healthcare solutions. For cooperation with developing countries the promotion of sustainable development, including circular economy approaches and by providing assistance for an evidence-based transformation of their health policy-making could be important drivers of work. Horizon Europe's cluster 1 is well positioned to contribute to the realisation of EU development policy objectives for the health sector and in particular in the following priority areas: (i) Disease Prevention and Health Promotion; (ii) sustainable and efficient Health Systems and Healthcare Financing; (iii) e-health/ digital technology for health; iv) AMR/ Infectious diseases/Pandemic Preparedness/ Health Security. Such priority areas should always take due account of low- and middle-income partner countries' own priorities.

In order to achieve the greatest impact and benefits for the health and well-being of its population, it is essential that the EU continues its international efforts in cross-border cooperation, coordination and alignment. This includes major international initiatives and established multilateral networks, e.g., in the area of infectious diseases, non-communicable diseases, rare diseases, brain research, and -omics and environment and health.

In addition, European research and innovation partnerships may involve international partners, in particular when addressing global health issues (health, environment and pollution; poverty-related and neglected infectious diseases; AMR), where a critical scale of resources, patients and health data calls for international approaches (genomics; personalised medicine; rare diseases), or where international partners offer access to critical know-how, resources and best practice (incl. on governance models and policies for cost-efficient and sustainable quality health care systems and services). Moreover, if research and innovation is expected to provide evidence for better informed policies and clinical practice, the involvement of normative or standard-setting international bodies, like WHO, may be essential.

6. European Partnerships

Partnerships provide mechanisms to consistently aggregate research and innovation efforts into more effective responses to the policy needs of the Union, developing close synergies with national and regional programmes, bringing together a broad range of actors to work towards a common goal, and turning research and innovation into socio-economic results. As such, they are powerful instruments to address global challenges by translating common priorities into concrete roadmaps and coordinated implementation of activities. EU-funded health research and innovation played a pioneering role in establishing and testing first approaches and forms of cooperation between

public and private funders, both within Europe and at international level. Under the previous research and innovation programme, Horizon 2020 (2014-2020), 36% of the budget allocated to collaborative health research and innovation was invested through European health research and innovation partnerships (€2.680bn of €7.472bn).

For the requested rationalisation and reform of European Partnerships under Horizon Europe, the following two considerations were taken into account under Cluster Health, mainly to increase the openness and reduce the number of partnerships:

1. Widening the scope and/or objectives of partnerships, e.g.
    - to widening participation
    - to extend private sector participation and improve leverage of funding
    - to set the ground towards better uptake and systemic impact of related research and innovation
2. Discontinuation and merging partnerships
    - to simplify the funding landscape, improve coherence and increase transparency
    - to create (additional) economies of scale

Following these considerations, the following five co-funded European Partnerships are proposed for the first four years of Horizon Europe:

1. "Health and Care Systems Transformation" (as of 2021);
2. "Chemicals risk assessment" (as of 2022);
3. "Fostering an ERA for Health Research" (as of 2023/2024);
4. "Personalised Medicine" (as of 2023);
5. "Rare Diseases" (as of 2024);
6. "One Health AMR" (as of 2023/2024).

In addition, two possible institutionalised European Partnerships (based on Article 185/187 TFEU) are proposed in the area "Faster development and safer use of health innovations for European patients, and global health" set by the legislator:

1. "EU-Africa research partnership on global health security to tackle infectious diseases" (as of 2021);
2. "Innovative Health Initiative" (as of 2021).

On the one hand, these partnerships provide significant leverage of investments and alignment on common priorities which allow sharing expertise, resources and the financial risks involved and thus achieving critical scales that a single member state or company would not be able achieve alone. On the other hand, they allow raising awareness and attracting interest from policy-makers, stakeholders and the wider public as well as gaining support from additional partners. As opposed to regular calls for proposals, a European Partnership can bring together a broader spectrum of stakeholders, both private and public, to align agendas across industrial sectors and/or public policies with a higher level of commitment and over a longer time-scale to implement activities needed for major changes and impacts. Traditional calls for proposals will neither achieve the same level of coordination, alignment or integration nor allow the same level of sharing of resources, responsibilities and financial risks involved. This is particularly true in cases where the number of disease cases (individual patients) is low, such as for rare diseases, or in cases where the market prospects (return of investments) do not match the financial risks involved, such as for poverty-related and neglected infectious diseases. Moreover, maximizing the impact on the health and well-being of citizens, patients or health systems requires building a long-term strategy and annual programming for a wide range of activities including research, innovation, networking, training, demonstration and dissemination, which is not possible through traditional collaborative projects.

Activities within the Cluster "Health" will also be closely related and collaborate with relevant EIT 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 start-ups, scale-ups and SMEs, the EIT KICs, in particular EIT Health (www.eithealth.eu), EIT Food (https://eitfood.eu/) and EIT Climate-KIC (https://www.climate-kic.org/) are well equipped to develop synergies and complementarities with Cluster "Health" activities.

7. Missions

Activities within the Cluster Health will be particularly relevant to the Mission(s) identified within the Cancer mission area. Depending on the scope of future specific Mission(s), further alignment may be identified with other missions such as within the Soil Health and Food mission area and with the Climate-Neutral and Smart Cities mission area.

ANNEX 2 - 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 the 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 research and innovation actions supported under this cluster. The key research and innovation priorities will respond to the following challenges:

1.1 Enhancing democratic governance

Democracies are more fragile and more vulnerable than in the past. The Freedom in the World Report (2019) 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 a 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, the effectiveness of public policy, non-discrimination, the protection of fundamental rights and the rule of law[70].

1.2 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 protection[71]. The EU's "United in Diversity" motto finds a tangible expression in cultural heritage. Historical sites and monuments, cultural landscapes, artefacts, museums, archives, as well as languages, customs, traditions, 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 restauration of cultural goods with innovative techniques in the cultural and creative industries with a view to the creation of jobs, growth and wealth.

The cultural and creative industries are at the heart of the creative economy. They make a significant contribution to the EU economy and play a crucial role in fostering innovation, promoting new sustainable and more inclusive business models. There is a need for further research on the most effective ways for enabling crossovers between cultural and creative industries and other sectors of the economy.

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

[71] 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.

1.3 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 like artificial intelligence in the production process could lead to automation rates of one third to two thirds of today's tasks.[72] According to other estimates, approximately 14% of jobs in the OECD countries are highly automatable, equivalent to 66 million jobs.[73] 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 countries[74]. 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.

Education and training, are key long-term factors in preventing and reversing inequalities and promoting equal opportunities, inclusion and social mobility. However, the educational outcomes of younger generations are still determined to a large extent by the socio-economic background of their parents rather than by their own potential. Promoting and ensuring inclusion and equity in education and training is thus fundamental in breaking these patterns.

In this context, it will be important to also reflect on the nature of economic growth and the need to better capture the different dimensions of social progress. It is increasingly important to distinguish between the different purposes of measurement: economic activity, social welfare, and sustainability and to develop relevant indicators.

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 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 biases[75].

[72] 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

[73] Nedelkoska, L. and G. Quintini (2018), "Automation, skills use and training", OECD Social, Employment and Migration Working Papers, No. 202, OECD Publishing, Paris.

[74] 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.

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

2. EU Policy Objectives

Cluster 2 Culture, Creativity and Inclusive Society will enable decision makers to meet challenges, adopt new paradigms, and policies for change in a context of fast paced transformations, transitions 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.

Cluster 2 will address EU priorities that give a new push to European democracy; support an economy that works for people; make Europe fit for the digital age; protect our European way of life; make Europe Stronger in the World; better manage migration and mobility; protect our cultural heritage.

3. Targeted Impacts

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

- Support policy action in favour of democracy, its stability, and its further development with a view to enhancing representation, participation, openness, pluralism, cultural participation, respect of diversity, non-discrimination, the protection of fundamental rights and the rule of law.
- Help tackle political extremism and polarisation and restore trust to governance.
- Help protect historical sites and monuments, cultural landscapes, artefacts, museums, archives, as well as languages, customs, traditions, and values.
- Promote research and innovation across the culture and creative sectors, fostering the value, protection access to and sustainability of culture across Europe.
- Support EU migration and mobility policies, both internal and external.
- Help reverse social, spatial, economic, cultural and political inequalities and their causes and promote gender equality.
- Assess and respond to the social, ethical, political and economic impacts of drivers of change (technology, globalisation, and changing demographics) in the wide variety of social, economic and territorial contexts in Europe.
- Contribute to a comprehensive European strategy for inclusive growth and upward convergence in employment and social affairs.
- Create high quality new knowledge, foster its diffusion and improve its take up in policy-making.

4. Key Research and Innovation Orientations

Research and innovation activities in this Cluster will help develop social, political and economic analysis, evidence based policy recommendations, innovations and foresight in all (three) Key research and innovation Orientations outlined below. New statistical tools and methodologies will be also developed, more easily accessible and comparable at EU level and with a better granularity in terms of findings (with due focus to distribution and territorial impacts).

In this context the Cluster will:

- Build up evidence and policy recommendations on enhancing democracy and good governance;
- Elucidate the societal – including political, ethical, cultural, gender 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;
- 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;
- Build evidence of the innovation capacity of cultural and creative industries and their role as innovation triggers in other economic sectors as well as other societal domains;
- 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.

4.1. Democracy and Governance

The implementation of the 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, civic engagement and gender equality. Activities will also enhance transparency, the effectiveness of public policy-making, accountability and legitimacy and will equally improve trust in democratic institutions, safeguard liberties and the rule of law, and protect democracy from multidimensional threats. Rich historical perspectives will set the frame for soundly understanding present developments and the help the mapping of future pathways. 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:

- Research and innovation will 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 dynamic meaning they have in our societies. This includes the analysis of the changing 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)[76]. It will help restore trust in governance, close the gap between perceptions and reality, and respond to threats to the electoral process and democracy[77]. 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.

- Research and innovation will help address the impacts and explore the potential of technological and scientific advancements, including big data, online social networks and artificial intelligence on democracy. Attention will be paid to issues of privacy, the use of personal data, accountability and the protection of citizens' rights as cornerstones of democratic trust. Activities 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

[76] 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.

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

network communication and their impact, and build on education and media literacy as gateways to democratic participation. Knowledge generated will lead to policy recommendations regarding the role of digital technology in participatory democracy and active and inclusive citizenship.

- Research and innovation will also target culture's value to democracy, by analysing relationships between a number of cultural and democratic dimensions such as active cultural engagement and democratic openness; political engagement; trust in society and well-being.
- Research and innovation will investigate the ways public decisions are taken based upon the interplay of available information, the role of evaluations and experimentations and public perceptions.
- Finally, activities funded under this research and innovation priority will systematically analyse the impact of economic, gender and socio-spatial inequalities on political representation and participation and explore ways to reverse negative trends. In this context, research will also examine issues related to economic democratic control, social and ecologic sustainability and social well-being.

4.2 Cultural Heritage

The implementation of these research activities will result in better access to, understanding of and engagement with cultural heritage. They will support the emergence of a sense of belonging based on the common roots of the diversity of European cultural heritage. Research and innovation results will contribute to European integration by providing better, wider and more equal access to culture, heritage and the arts. Horizon Europe activities will also enhance the governance and cooperation of European cultural heritage institutions and networks. Most importantly, they will improve the 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. Research and innovation will provide solutions for making the EU a world leader in 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. Research and innovation will also help the preservation of endangered languages. Finally, research and innovation will support European policies for cultural and creative industries contributing to sustainable growth and job creation.

- Support the EU’s policy objective in monitoring, safeguarding and transmitting cultural heritage, fostering cultural and creative sectors and promoting cultural diversity.

- Share and increase 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 new methodologies of digital humanities for ground-breaking, new interpretations of the past

- Build on the role of intangible heritage (e.g. language, spiritual beliefs, crafts, festivals, music, dance etc.), traditions, identities and new forms of cultural and artistic expression, in the development of new approaches for more cohesive, and sustainable societies.

- Promote new educational and training pathways and skills to adapt current and future cultural heritage protection practices; and the creation and promotion of new forms of cultural expression compatible with societal transformations (e.g. the data society).

- Promote policies and projects improving gender equality in the cultural heritage sector.

- Investigate the social construction, quality and usage of cultural heritage at the national, European and international levels.

- 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 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 the reuse of 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 cultural tourism.

- Research and innovation will contribute to sustainable development through research and innovation for the conservation, developing, accessing and regeneration of cultural landscapes.

- Promote new education models to foster the cross-overs between art and other disciplines (e.g. engineering, digital technology, physics etc.).

- Investigate the impact of creative and artistic intervention into innovation processes.

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 their fair distribution and social and economic resilience. Activities will support the governance of migration and the integration of migrants and populations of immigrant background. They will also contribute to EU migration and mobility policies, both internal and external. The overall 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 transformations.

- 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, develop human capital, 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. Research and innovation 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, demographic changes 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.

- Activities will give further impetus to the development of new indicators going beyond the mainstream ones (e.g. GDP) and making the case for a more holistic understanding of societal well-being.
- 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.
- Support policies for children and youth in a variety of fields, including educational opportunities and poverty, migration and integration, political participation, sustainability, the digital economy etc. Activities will also bring the benefits of digital transformation to education and training, by making optimal use of emerging technologies (such as AI, data analytics or blockchain). They will support innovative learning environments and provide teachers and educators with the adequate skills, knowledge and awareness of opportunities.
- Research and innovation 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 research and innovation orientation will also support EU migration and mobility policies. 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.

5. International Cooperation

The intervention areas under this cluster will benefit from drawing on insights and perspectives from international cooperation. Engaging in international cooperation will allow for a better assessment of challenges in their global, regional or local context.

To this end, work with international partners will be undertaken on issues such as multilateral governance, the drivers and governance of migration, the democratic governance of cultural diversity, and the crises in the EU neighbourhood. International collaborations will also allow for broader connections when addressing global trends in democratic governance, intercultural relations and cooperation on cultural heritage, inclusive growth, and decent work and fair working conditions in the context of globalisation.

6. European Partnerships

No European Partnerships are currently suggested under this cluster. However, a legislative procedure is ongoing concerning the Commission proposal on the Strategic Innovation Agenda of the EIT 2021-2027 that identifies Cultural and Creative Industries as a priority field for a new KIC, and that is relevant in the context of this cluster.

7. Missions

Depending on the scope of future specific Missions, activities within the Cluster Culture, Creativity and Inclusive Society might be particularly relevant to the Mission(s) identified within the "Climate Adaptation including Societal Transformation" mission area, as well as other mission areas.

ANNEX 3 - CLUSTER 3: CIVIL SECURITY FOR SOCIETY

1. Global Challenges and their Drivers

Security is one of the main concerns for the EU's citizens and is therefore among the top priorities for the Commission. While the threats of terrorism and crime within the EU remain serious, challenges like cyber-attacks are requiring coordinated responses and novel concepts. Illegal migration caused by ongoing insecurity and economic instability in the EU's neighbourhood as well as an increase of legal movements of persons and goods are requiring new technological solutions to allow for more efficient and better integrated border management. Disasters, whether natural or man-made, can put at risk important societal functions, such as health, energy supply and government. The aim is to prevent and reduce the loss of life, harm to health and the environment, economic and material damage from disasters, ensure food security as well as to improve the understanding and reduction of disaster risks and post-disaster lesson learning. Climate change is likely to exacerbate security challenges outside of disaster events. Research can play an active role in this respect by supporting the development of innovative and collaborative solutions.

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' as well as for this purpose supporting a competitive European civil security industry sector. It will address the challenges arising from persistent security threats like terrorism and crime, including cybercrime, as well as natural and man-made disasters, including the ethical dimensions of those challenges.

As these challenges are rapidly evolving and technological progress is making a response increasingly complex, security research can serve as a tool to move from a reactive approach to security to a proactive approach based on foresight and anticipation. Among other, EU security research is a cornerstone of the Security Union enabling innovation in technologies and knowledge and furthermore contributes to a more competitive and, when necessary, autonomous European security industry. Research will enable opportunities that will be offered by emerging technologies such as e.g. Artificial Intelligence while at the same time preventing the malicious use of such same technologies. Leveraging EU-controlled technologies (e.g. Galileo) could also strengthen European industry's competitive advantage and society's resilience in safeguarding its critical infrastructures.

Whereas research and innovation activities under the Horizon Europe specific programme and therefore this cluster will have an exclusive focus on civil applications, coordination with EU-funded defence research will be sought in order to strengthen synergies, recognising that there are areas of dual-use technology. Duplication of funding will be avoided.

2. EU Policy Objectives

This cluster will support implementation of EU policy priorities relating to security, including cybersecurity, and disaster risk management. In order to ensure a best possible impact, the activities under the cluster are aiming at supporting concrete EU policy as defined for each area of intervention:

- Research and innovation activities in relation to disaster risk management will support implementation of the Union Civil Protection Mechanism, the EU Climate Adaptation Strategy, EU environmental policies such as the Seveso III and Flood Directives, 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, research and innovation will support implementation of the EU CBRN and Explosives Action Plans.

- As regards protection and security, research and innovation activities 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, as well as on fighting crime, including cybercrime and terrorism.

- Research and innovation activities will help to put into practice the EU Maritime Security Strategy and, as concerns EU maritime borders, take in role in developing integrated border management.

- Cybersecurity, as addressed by the digital and privacy policy of the Union, in particular the NIS Directive, the GDPR, the EU Cybersecurity Act, and the future e-Privacy Regulation will benefit from research and innovation activities so as to keep up with rapid technological developments and the understanding of emerging trends in the cyber-domain.

As an overarching priority, effective support will be provided to practitioners, law enforcement agencies, first responders and other public authorities or private entities which are ensuring the security of European citizens, infrastructures and assets in general.

Alongside supporting EU policy responses to security challenges, research and innovation within this cluster will boost the competitiveness of companies and research organisations in the EU civil security sector and thereby strengthen the EU's technology and industrial base in this sector By doing so, it will also support European strategic autonomy in critical security areas such as cybersecurity; cloud services; artificial intelligence; critical raw materials and components; EU space technologies, systems and the EU Space Programme and its components (e.g. Copernicus, Galileo and EGNOS, SSA and GOVSATCOM).

All these activities will help to achieve SDG 16 (peace, justice, rule of law) and other relevant SDGs.

3. Targeted 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, public services, financial services, 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 Research and Innovation Orientations

Within this cluster, civil security research will be progressively framed under the wider umbrella of

a capability-based approach to capacity building in the security sector. This approach focuses research and innovation activities as a contribution (notably, but not exclusively, 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 research and innovation activities in this cluster needs to recognise that Member States have the front line responsibility for security but cannot address transnational threats in an optimal way when acting on their own. Research and innovation can support this process, including by improving cooperation and exchange of information, and by increasing knowledge about relevant human and societal factors. Research and innovation projects in this cluster should continue to involve practitioner end-users (usually relevant national authorities) alongside researchers and industry. EU-level research and innovation to fill capability gaps can increase the impact of EU responses by reducing risks of fragmented approaches, promoting better use of resources and fostering the development and use of standardised solutions. Deployment and market uptake of successful research and innovation needs to be promoted, including through implementation-oriented research.

An integrated approach is needed so as to take into account short-term needs stemming from fast-changing security threats but also to promote a proactive 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 into account human factors and the societal context, and to ensure the respect of fundamental rights, including privacy and protection of personal data. Citizens and communities also need to be engaged in the process of making society more resilient via research and innovation-enabled technological, non-technological and social innovation. SSH (social sciences and humanities) disciplines need to be integrated into security research, including when relevant in research focused on technologies. 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 research and innovation 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 allow for reduced losses from disasters, both in terms of impact on citizens and of environmental, economic, material and immaterial damage, in particular in vulnerable groups and areas, including heritage sites.

Disaster risk management can be improved through related research and innovation activities. This includes a better understanding of the disaster risk management cycle for incidents with a high impact but a low probability of occurrence ("Lo-Hi/HILP"events). In this context research will enhance societal risk awareness, prevention and preparedness, including through early warning and alert systems and a capacity to be better prepared (including psychologically) and able to respond to natural and man-made disasters (of accidental or terrorist origin).

With the help of enhanced technological solutions and concepts, relevant communities can be better involved in the development and implementation of plans supporting cost-effective risk reduction and societal resilience, including for the evacuation of vulnerable populations.

An improved response to disasters requires better tools and procedures for the coordination of cross-border incidents, more integrated and interoperable technologies, tools and methods to support emergency procedures which are developed with all relevant actors. Finally, research can lead to the creation of standards on the EU-level for response and emergency planning.

Targeted research and innovation tackles cross-sectoral and multilevel governance on disaster risk management at EU level which manages also trade-offs in policy-making. This includes not only civil protection as such but related areas such as land management, agriculture and rural development, as well as environment, climate and energy. It will further contribute to the creation of methodologies to be defined for 'resilient by design' infrastructure. As a result of improved

knowledge of human and societal factors, post-disaster recovery will respect local communities' aesthetic-historical-social values as well as quality standards for cultural heritage sites.

More specifically, there are four areas within the priority 'Disaster-resilient societies' which require more targeted research and innovation:

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

There is need for a deeper understanding of CBRN-E risks (also in relation to new, widely available technologies) as well as for the creation of specific measurements, including standards and certification for detection equipment, better comparability of data, both within EU and beyond.

CBRN-E incidents create unique risks also for first responders. Security research can help mitigate such risks by identifying and filling gaps in capabilities for response, mission critical communication and protection equipment for first responders. In addition projects will focus on capabilities for detecting and evaluating threats and incidents, or detection and triage of victims lead to an enhanced preparedness for and response to incidents.

Research and innovation should further explore methods for seamless cooperation between relevant actors (e.g. law enforcement and civil protection authorities, health), including strengthening internal-external links (EU CBRN Network of Centres of Excellence) and with key international partners (NATO, OPCW, Interpol).

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

A consequent improvement in climate risk management will rely on more exact forecasting of occurrences and impacts, and understanding of climate change related risks and vulnerabilities, including their application within emergency planning. This is to be explored in connection with a generally more flexible adaptation to climate change impacts, including cascading and spill-over effects and improved cross-border management, both within the EU and at wider transboundary levels, of new and emerging climate change induced risks and impacts.

This includes science-to-practice knowledge exchange and use of sustainable, cost-effective and inclusive approaches, like nature-based solutions.

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

Given the devastating potential of such disasters, research and innovation needs to support better preparedness for and response after such events. This includes better and technologically advanced civil protection capacities, notably faster detection and evacuation of victims.

d) Pandemics and emerging infectious diseases[78]

The most critical part in fighting pandemics and infectious diseases is earlier detection of outbreaks. Here exists a big potential for improvement via targeted research and innovation. Besides the detection, projects can explore ways to better respond, for example by European Pandemic Preparedness Plans[79] informed by scenario development, enhanced capabilities 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 support air, land and sea EU border management and is expected to allow for more effective implementation as a result of improved knowledge about human and societal factors underlying cross-border threats. The European Border and Coast Guard Agency (Frontex) will be closely associated with relevant research and innovation activities, taking into account its

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

[79] 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).

central role – proposed by the Commission (COM(2018) 631) – in defining capability requirements for the European Border and Coast Guard.

An effective border management relies on comprehensive information and its exchange between Member States and EU Agencies. Research and innovation will therefore enhance the interoperability and performance of relevant EU information systems, leading to better and faster exchange as well as analysis.

With specific reference to movement of persons, whether crossing borders legally or illegally, the contribution of the European Border and Coast Guard Agency in identifying the relevant research requirements will be crucial. This should lead to the development of tools and methods for Integrated Border Management, in particular to increase reaction capability and capacity for border surveillance and monitoring movements across external borders. This will allow for better risk-detection, incident response and prevention, and identification of and response to crime.

Concerning the flow of goods, projects are expected to address requirements identified by EU customs authorities, most notably improved detection of fraudulent activities at border crossing points and throughout the transportation and supply chain.

4.2.2 Protection of public spaces[80]

The core target of this priority is improved security and public safety, while at the same time preserving the open nature of urban public spaces. All measures to be explored by research and innovation in this area should ensure that citizens can continue their daily lives without major intrusions.

To achieve higher security for public space, research will identify concepts for prevention, preparedness and response of urban actors (city authorities, law enforcement authorities, public/private service providers, first responders and citizens) in response to threats of terrorist attacks in public spaces.

Technological innovations can be used to design public spaces to be more secure, also with the help of advanced vulnerability assessments. They can increase the capacity to protect spaces against attacks with manned or unmanned vehicles and can help to detect firearms and other weapons, as well as CBRN-E -materials being brought into public spaces. In case attacks cannot be prevented, enhanced effectiveness of mitigation measures including through strategies to reduce vulnerability and strengthening the resilience of possible targets have the potential to reduce the potential impacts of such attacks. Advanced data-analysis in real-time can critically reduce the time-to-react for first responders.

4.2.3 Security and resilience of infrastructure and vital societal functions[81]

Activities conducted under the umbrella of this priority will ensure security and resilience of basic societal functions such as healthcare, law enforcement, energy, mobility, public services, financial services, communication and logistics infrastructures and networks (both physical, on ground and in space, and digital), so as to minimise societal disruptions.

In order to allow for effective countermeasures, there is a need for better risk- and vulnerability assessments, especially taking into account systemic threats, interdependencies between different infrastructures and cascading risks taking into account the cross-border dimension.

To better prevent and detect attacks (including cyber and hybrid attacks) or natural hazards as well as to allow for quick response, research and innovation will bring new tools for security actors (police, relief workers, disaster managers, crisis managers) notably in the fields of communication, data analysis and advanced robotics, with a view to developing largely autonomous detection and response capabilities.

Technologies and new concepts and cooperation instruments will help mitigation of consequences and allow for faster recovery of service performance levels, including leveraging the potentials of big data analysis and artificial intelligence.

[80] This priority also relates to the intervention area 4.1 Disaster-resilient societies.
[81] This priority also relates to the intervention area 4.3 Cybersecurity.

4.2.4 Maritime security

This priority addresses capability requirements identified by the EU Maritime Security Action Plan. Research activities will therefore enable better maritime surveillance, risk awareness and management of EU critical maritime infrastructure border protection and coast guard functions. The scope of maritime security in this regard includes man-made and natural disasters, accidents, climate change as well as security threats such as terrorism and piracy, cyber, hybrid and CBRN threats.

The EU Maritime Security Research Agenda lays down in this regard specific areas to be addressed, including cybersecurity, interoperability and information sharing, autonomous systems, networking and communication systems and multi-purpose platforms.

4.2.5 Fighting crime and terrorism

This priority aims to bring improved prevention, investigation and mitigation of impacts of criminal acts, including of new/emerging types (such as those resulting from digitisation and other technologies). This needs to be based on a deeper knowledge of human and social aspects of relevant societal challenges, such as violent radicalisation, child sexual exploitation, trafficking of human beings, corruption and cyber criminality, including support to victims.[82] Research can further help to transpose such knowledge into the operational activities of EU law enforcement agencies and civil society organisations.

Research and innovation will support law enforcement agencies in better tackling crime, including cybercrime and terrorism as well as the different forms of serious and organised crime (such as smuggling, money laundering, identity theft, counterfeiting of products, trafficking of illicit drugs and of falsified/substandard medicines, environmental crime or illicit trafficking of cultural goods[83]) by developing new technologies, tools and systems (including digital tools, e.g. artificial intelligence). This refers especially to 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.

In addition to improved knowledge and prevention, projects will deliver operational tools for enhanced criminal investigation capabilities for law enforcement agencies. This covers a broad range of activities from forensics, big data management to the investigation of cybercriminal activities, improved cross-border cooperation and exchange of evidence.

With regards to CBRN-E threats, research and innovation allows to generate knowledge for counter-terrorism on the continuously evolving methods related to dangerous chemicals, and the development of technologies to counter and respond to related incidents.

4.3 Cybersecurity

Supported by research and innovation under this priority, citizens, public authorities and companies, including SMEs, will be empowered to protect their data and online activities notably when using social media.

This requires a resilient critical digital infrastructure, both private and public, that 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. Research should strengthen European cybersecurity industrial capacities and thus increase the strategic autonomy vis-à-vis foreign technologies.

Research and innovation will support in this regard use of innovative digital technologies, including self-healing, artificial intelligence, cryptography, massively distributed computing and storage, as well as quantum technologies to increase data security and augment cybersecurity. It will further allow for security-relevant innovations in the area of governance of algorithms, coding architecture and programming languages. All these measures are aiming at defending the EUs high standards

[82] 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'.

[83] 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'.

concerning right to privacy, protection of personal data, and the protection of fundamental right in the digital age on the global stage.

The frequency and complexity of cyber-attacks from state and/or criminal actors is increasing rapidly. Research and innovation will therefore need to support the effectiveness and coordination of measures to respond to them.

An emerging threats in the cyber-area are attacks against democracy and European societies, including electoral meddling, fake news, and online forgeries and manipulation. In order to allow for an adequate response for the coming years, research is necessary to better understand the nature and source of such attacks as well as technologies and strategies to counter them.

For all activities against cyber-threats, the architectural principles of 'security-by-design' and 'privacy-by-design' will be implemented in digital technologies and their applications, such as 5G, industry 4.0, artificial intelligence, Internet of Things, block chain, quantum technologies, mobile devices and connected cooperative and autonomous mobility and energy.

A legislative procedure is ongoing concerning the Commission proposal for a Cybersecurity Competence Centre and Network (COM(2018) 630)."[84] The proposal is subject to ongoing inter-institutional negotiations.

5. International cooperation

In order to achieve the right balance between the need for international cooperation (including with relevant international organisations) to achieve many of the desired impacts, whilst at the same time protecting EU security interests and strategic autonomy:

- in the area of disaster resilience and response, international cooperation will be strongly encouraged given the value of cooperating internationally in particular in developing technologies for first responders;
- in the areas of protection and security (including border management, protection of infrastructures, fighting crime and terrorism) and of cybersecurity, international cooperation will be encouraged where appropriate and relevant.

6. European Partnerships

No European Partnerships are currently suggested under this cluster.

7. Missions

Depending on the scope of future specific Missions, activities within the Cluster Civil Security for Society might be particularly relevant to the Mission(s) identified within the "Climate Adaptation including Societal Transformation", as well as other mission areas.

[84] The proposed Regulation is still under discussion.

ANNEX 4 - CLUSTER 4: DIGITAL, INDUSTRY AND SPACE

1. Global Challenges and their Drivers

Digitisation and technological progress, including Space, 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, travel, 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;[85] enable production and consumption to respect the boundaries of our planet; and maximise the benefits for all parts of society in the varied social, economic and territorial contexts in Europe.

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, needs continued EU support for the development and uptake of smart and clean technologies. However, the EU cannot do this alone. Partnership initiatives will 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; and by a lack of scale-up and technology diffusion capacities. Long investment cycles are needed in key EU industries, notably the energy-intensive industries.

Key facts and figures:

- Europe's industry and companies provide a livelihood for millions of Europeans and play a central role in the EU's prosperity, economic leadership, and social cohesion. After a long decline, industry's share of the economy has increased in the last five years and currently contributes around 17.5% of the European Union's GDP (22% including construction) and directly provides work to close to 24% of Europe's (manufacturing including construction)[86].
- 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 chain has shrunk gradually over the past 20 years.[87] Most recently (2017-18), EU companies reduced their global R&D share in ICT industries by more than 8%.[88]
- Space technologies, data and services have become indispensable in the daily lives of European citizens: when travelling, using mobile phones and car navigation systems, watching satellite TV, enhancing weather forecasts, improving emergency services and responding to other global challenges. The value generated from **space related activities** is estimated between EUR 46 to 54 billion representing a share of 21% of the worldwide business. In

[85] 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

[86] The contribution of industry for employment and growth is likely to be even higher as these figures do not account for the importance of industry-related services and the trend of servitisation, which are not visible in the sectoral statistics.

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

[88] 2018 EU Industrial R&I Investment Scoreboard http://iri.jrc.ec.europa.eu/scoreboard18.html

addition, the capacity to access and use space is a strategic asset for Europe and its Member States, which impacts many other sectors,[89] and opens up many business opportunities for early-stage and high-tech companies, especially in combination with digital technologies, other sensors and sources of data. The EU must make the most of these opportunities by fully developping and exploiting the potential of European Space Programmes and its components Copernicus, EGNOS and Galileo, SSA and GOVSATCOM. The emergence of 'New Space' since 2010, can be seized to open up new business possibilities in Europe, by enlarging the number of players involved. The potential of the downstream segment of the space sector can be better exploited, in particular Galileo and Copernicus. Such applications can help tackle global challenges, create high-skilled jobs and open up new market opportunities for businesses.

- Research and innovation is 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.[90] The R&Dconducted 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%).[91] In digital for example research and innovation intensity is about 5% as opposed to 12% in the US and 11% in Japan.[92]
- The EU shows higher shares of research and innovation 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 the EU are 4 times less than in the US. China set up a strategy plan[93] 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 ten strategic sectors. The strategy seeks to raise the domestic content of core components and materials to 40% by 2020 and 70% by 2025.[94] 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. . If we consider that investment in Space systems has a well-tested multiplier effect that trickles down 3-4 times into the economy, we identify a source of the US advantage in other high-tech sectors.
- 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

[89] Space-based services provide immediate information in support of numerous Union policies and industry sectors; it is calculated for example that more than 10% of EU GDP is enabled by GNSS.

[90] Re-finding Industry. Report of the independent HLG on Industrial Technologies, 2018.

[91] Non-EU28 countries figures are from 2015. EUROSTAT database

[92] 2012 PREDICT REPORT
http://is.jrc.ec.europa.eu/pages/ISG/documents/OnlineversionFINALPredict2012withnumbersv2.pdf

[93] New Generation of Artificial Intelligence Development Plan

[94] Made in China (MIC) 2025

greenhouse gas emissions, pollution and waste, as well as harness the opportunities emerging from this transition.

An accelarating global resource consumption has increased environmental pressures beyond sustainable levels. 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. New technologies should notably reduce energy consumption and be part of a circular economy value chain which will contribute to Europe's competitiveness in a context of increased sustainability standards.

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.[95] [96]
- The global energy consumption by industry grew by an average of 1.3% each year 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 %).[97]
- According to the International Energy Agency (IEA),[98] global industrial emissions in 2016 amounted to 8.3 GtCO2, or 24% of global emissions. Amongst the 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. Asprocess emissions account for a significant share of the emissions in these and other energy intensive industries, reshaping of whole process chains will be necessary. To achieve climate-neutrality in 2050, significantly larger investments in deep decarbonisation technologies are needed. These investments are estimated to be around an additional EUR 5.5 billion per year for the above mentioned sectors, an 88% increase compared to the baseline scenario.[99]
- The rapid expansion of the digital sector has environmental consequences, including considerable increases in the extraction of critical raw materials, in energy consumption (e.g. from digital infrastructure and other auxiliary equipment), as well as in Green House Gas emissions (4% of global annual increase[100]).

(iii) Developments in industry and in enabling technologies have the potential to enhance **social inclusion**; at the same time, there is a growing risk of digital divides. Workers, regions and societies are faced with extremely fast transformations, including the impact of digitisation and climate change.

The challenges in Europe are the rapid adoption of new technologies and their impact on the labour market and the nature of work; skills mismatches and increasing wealth concentration. Other **concerns regarding new technologies** include trust and ethical considerations. All the new approaches must 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:

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[95] A Clean Planet for All, COM(2018)773 final

[96] 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%."

[97] European Environment Agency database.

[98] https://www.iea.org/tcep/industry/

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

[100] https://theshiftproject.org/wp-content/uploads/2019/03/Lean-ICT-Report_The-Shift-Project_2019.pdf

- There are substantial variations in the level of economic activity and labour market performance across Europe, including technological specialisation and research and innovation 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.[101]
- Evidence indicates a considerable accumulation of wealth by a small segment 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.[102]
- 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.[103] The lack of skilled individuals and talents risks slowing down investments. For instance, 9 out of 10 manufacturers are struggling to find the skilled workers they need. 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.
- New technologies such as digitisation and automation will reshape economies and societies in all the regions and will have differentiated impacts across the regions and also across the regions within one nation in Europe and globally.[104]

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.[105] Three objectives will be pursued across the cluster, in synergy with other EU instruments and initiatives:

Ensuring the **competitive edge and sovereignty of EU industry**: Key enabling technologies, including digital ones, 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 leadership in global markets; and promise 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 less dependent, the EU must tackle missing segments in key strategic value chains. To begin with, it must ensure a secure, sustainable, responsibly-sourced supply of raw materials and increased autonomy in critical 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 competitive edge is its technological sovereignty, to safeguard security of supply and European industry's ability to export its products as part of a global value chain. This is the case of digital technologies for instance, where fast development is creating new dependencies and vulnerabilities across the economy and society (e.g. cyberattacks, espionage,

[101] The Geography of EU Discontent
[102] Future of Work, Future of Society - European Group of Ethics in Science and New Technologies, December 2018
[103] Digital Economy and Society Index, https://ec.europa.eu/digital-single-market/en/desi
[104] OECD Regional Outlook 2019 - Leveraging Megatrends for Cities and Rural Areas, http://www.oecd.org/regional/oecd-regional-outlook-2019-9789264312838-en.htm
[105] Investing in a smart, innovative and sustainable Industry A renewed EU Industrial Policy Strategy, COM(2017)479.

hacking/sabotage, intellectual property theft, electoral interference) and leads to the emergence of new threats to strategic autonomy. For the EU Space industry for instance, non-dependence is key for a number of components used for satellites, space traffic management capabilities and launchers In addition, research supported by Cluster 3 on cybersecurity can ensure opportunities offered by emerging technologies are harnessed, while at the same time preventing the malicious use of such same technologies. Leveraging EU-controlled technologies (such as Gallileo) could also strengthen European industry's competitive advantage and society's resilience in safeguarding critical infrastructures.

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.

A further factor for success is to combine the applied research with research in less mature and emerging technologies, through open research with a longer-term purpose.

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, decarbonise production processes, protect the environment and enable a circular economy. Europe should take the lead in this approach.

The breakthrough technologies and solutions[106] to be developed in this cluster will, in conjunction with new business models, contribute to bring about climate-neutral and globally competitive EU industries by 2050, thereby delivering on theLong-term strategy, calling for a climate-neutral Europe by 2050;[107] and foster a circular economy.[108] 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 (i.e. Copernicus), 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.

A **major contribution to inclusiveness**: From the outset we must involve and empower workers, consumers and firms to make sure that they co-design, have access to, and take up, these technologies (reflecting age, gender and other diversity issues where appropriate). *In conjunction with other programmes and initiatives*, there must be adequate support for the development of skills, the involvement of the young (for example through living labs or learning factories), and the development of regions, cities and rural areas – ensuring a socially fair transition not leaving anyone behind. We must also pay due regard to safety, and to the impact of technologies and industrial transformation on people and societies, including changes in behaviour needed for sustainability.

A key aspect of the EU approach to technology development will be 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 requirements[109] for trustworthy AI identified by the High-Level Experts Group established by the Commission.

[106] including low-power processors and computing architectures

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

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

[109] 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)

The interaction of science, technology, social sciences and humanities will be important in this respect, as will be the input of the creative sector and artists to sustainable inclusive innovation and to human-oriented technologies.[110]

Beyond 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. Targeted impacts

In line with the priority of the Commission of **a Europe fit for the Digital Age**, EU sovereignty will be pursued within key strategic value chains,[111] by supporting digital, other key enabling and space technologies. This includes leadership in advanced materials, human-centric artificial intelligence,[112] block chain, high-performance / quantum computing, algorithms and tools supporting data sharing and data usage, and space technologies. Examples of key targeted impacts supporting this priority include:

- **Digitising and transforming industry**;
- **Increased sovereignty** in **key enabling technologies and digital technologies**, in strategic value chains, and a **secure and sustainable supply of raw materials**;
- **A European approach**, involving a human-centred and ethical development and use of new technologies;
- **Industrial leadership** in **key enabling, digital and space technologies and uptake of new technologies, and space services and data,** through technology infrastructures and increased autonomy in strategic value chains.

In line with the priority of the Commission of **a European Green Deal**, and with the strong support expressed by stakeholders in the public consultation (over 80%), EU industries will become climate-neutral, circular and clean. This can be done by, for instance, by developing the necessary breakthrough technologies and solutions for zero-emission and zero-waste factories, with plants in several regions contributing to the fight against climate change and the protection of the environment. The cluster will enhance Europe's position as a world leader in climate-neutral industry, the circular economy and clean technologies. Examples of key targeted impacts supporting this priority include:

- Achieving increased autonomy in **critical raw materials**, through substitution, resource efficiency and recycling and primary production;
- **Greening ICT**, for instance by developing low energy consumption components and combination of approaches, to enhance the efficiency of computing by several orders of magnitude;
- **Space services** will also contribute to climate mitigation and environmental protection, mobility and security.

In line with the priority of the Commission of **an economy that works for people**, industry will be providing one out of four jobs, having set the transition to climate-neutrality before 2050 on a solid ground. Input from the activities under this Cluster will inform up-skilling training programmes, and lead to attractive and creative jobs across Europe, while maintaining a two-way engagement with society with regard to developing technologies. One example of a key targeted impact supporting this priority is:

- **Increased inclusiveness**, by helping industry provide **attractive and creative jobs in Europe**; making a two-way engagement in the development of technologies a reality;

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[110] www.STARTS.eu

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

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

developing human-centred approaches; promoting social innovation; and helping foster skills and empower the young in, for instance, the digital and advanced manufacturing areas.

In line with the priority of the Commission of **a stronger Europe in the world**, and with the strong support expressed by stakeholders in the public consultation (over 60%), the cluster will pursue increased autonomy in critical raw materials through substitution, efficiency and recycling and primary production; and world-leading European technologies for climate neutrality and circularity.

The research and innovation priorities that follow are associated with more specific impacts, while they all contribute in different ways to the three main policy objectives, as shown in the table below.

Key research and innovation orientations of Cluster 4	**Policy objectives**		
	Competitiveness and Autonomy	**Climate-neutral, Circular and Clean Industry**	**Inclusiveness**
1 Manufacturing Technologies	ALL PRIORITIES	Enabling circular and locally manufactured products	Skills, SME inclusion, localised manufacturing
2 Key Digital Technologies		Enabling sustainability in various applications	Skills, SME inclusion
3 Advanced Materials		Enabling sustainability in various applications	Skills, SME inclusion, Societal engagement
4 Emerging Enabling Technologies		Enabling sustainability in various applications	Societal engagement
5 Artificial Intelligence and Robotics		Enabling sustainability in various applications	Skills, Ethics, Societal engagement, SME inclusion
6 Next Generation Internet		Enabling sustainability in various applications	Skills, Societal engagement, SME inclusion
7 Advanced Computing and Big Data		Enabling sustainability in various applications	Skills, Societal engagement, SME inclusion
8 A globally competitive Space sector		Enabling sustainability in various applications	Skills, SME inclusion
9 Circular Industries		Circular Economy	Skills, SME inclusion

10 Low-carbon and Clean Industries		Carbon neutrality and clean environment	Skills, SME inclusion
11 New services from Space for the EU society and economy		Enabling sustainability in various applications and long term sustainability of the access to space	Skills, SME inclusion

4. Key Research and Innovation Orientations

Key research and innovation 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 contribute to sustainable prosperity for all and reinforced strategic advantages in terms of increased productivity, enhanced job quality and reduced environmental footprints. They are also directly relevant for activities in clusters related to health, energy and mobility. Priorities include:

- Expanding the creation 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.
- Capitalising on the digital transformation to raise productivity and realise shorter innovation cycles, new business models, urban and distributed manufacturing, higher quality products and enhanced workplace skill-sets.
- More circular economy, with products reused in new 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, medicine, engineering, machine learning and manufacturing and processes such as biomachining, biomimetics, biomechanics, and bio-inspired digital manufacturing.
- 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, including in cities and in peri-urban and rural areas; supporting leadership in strategic value chains; and offering new products for new markets.

The Made in Europe co-programmed partnership could bring a concerted, broadly based, human-centric approach to these activities.

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. The EU's current strong industrial value chains (e.g. automotive, aerospace, machinery and agri-food) are increasingly dependent for their

competitiveness and autonomy on access to cutting-edge key digital technologies. Mastering their development and integration in complex smart systems is vital to a sustainable, sovereign and competitive Europe.

At the heart of digital transformation is the continuous progress in key underlying electronics and photonics components and systems, software technologies and connectivity platforms. Further scaling in mainstream nanoelectronics raises physical and economic challenges, but progress in digital components and devices continues through disruptive innovations, thanks to new materials (such as graphene, flexible substrates), low-power electronics and alternative processing concepts, like neuromorphic, that map cognitive processes into electronic circuits, quantum information processing and open-source hardware. 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.

Technologies supporting the concept of distributed intelligence will be essential to guarantee the required levels of energy efficiency, real-time operations and security. This includes advances on multisensor-based systems providing high levels of smartness and integrated in a wide range of application contexts (body, home, automotive etc.).

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 through 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.

There are opportunities ahead for European players in innovative computing (neuromorphic or quantum) as well as in sensing (miniaturisation of photonic sensing with electronics co-integrated). For both future technologies photonic and electronic hardware play a significant role. Another aspect is the acquisition and aggregation of physical data for further processing with AI methods (e.g. used for machine vision in production processes). Therefore, stronger integration of software with electronic and photonic hardware in innovative computing architectures and their packaging into smart miniaturised multi-sensing systems should be addressed as priorities.

Emphasis will be put on trusted electronic components and systems. Embedded security, reliability and usability, as well as easier programmability, throughout products and services life-cycles, will contribute to citizens' confidence in digital technologies.

The development of low-energy computation solutions will also significantly contribute to higher levels of sustainability, while the increased use of photonics (light based technologies) will open up new possibilities for end user industry to innovate in new products and services.

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

4.3 Advanced Materials

New material development has historically been closely linked to significant industrial and societal advances and remains a key technology for responding to virtually every global challenge. Material science and technology will also be essential to the "European Green Deal", and in particular its challenges of climate neutrality, transition to a circular economy, and a zero pollution Europe".

Europe should aim to develop advanced and sustainable materials, designed to meet specific needs (societal or industrial) so that they benefit the widest possible community of users. These materials shall be safe, sustainable and competitive within the circular economy and respect regulatory standards.

To reach climate neutrality in Europe, it is necessary to promote disruptive materials science that provides solutions at the industrial scale, e.g. in the form of catalytic systems that will overcome challenges in current renewable energy systems (generation, conversion and storage). Such new production concepts will combine high efficiency with changing and more variable feedstock (CO_2 and waste) and as such will support the decarbonisation of energy and the material needs of EU industries.

Energy efficiency is also a contributor to climate neutrality and therefore lightweight, functional and smart materials are of importance. In addition, materials that are able to mimic biological functions will be desirable for a wide range of commercial product applications.

Developing new sustainable materials will further reduce Europe's dependency on critical raw materials, and research and innovation on the circularity of materials and recycling systems will contribute to achieve this goal.

The development of advanced materials for innovative medical products and devices directly contributes to the well-being of European citizens. In addition, advanced materials will provide solutions for challenges related to health, fire performance and sustainability of building materials contributing to the safety of Europe's citizens.

Product design and development will benefit from the involvement of creative professionals, curators, restorers etc. who support an "innovative materials by design" approach, and which will be an efficient way to answer the growing consumer demand for innovative products combining functionality with aesthetics, as well as the need to protecting artefacts of cultural heritage.

The materials development cycle is long and entails several steps such as characterisation, modelling, processing, upscaling and engineering, including a lengthy assessment in industrial environments. 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, including risk assessment. They will reduce the technological risk associated with the development of innovative materials and products, thus attracting more investors, and cutting the time to market.

A coherent approach to risk assessment and life-cycle methodologies will ensure the development and monitoring of a cradle-to-cradle approach, and will also further support the principle of the European eco-label. Advanced sustainable materials will also need to be taken up in industrial value chains.

Regulation, corresponding testing methodologies and risk assessment standards must be improved and updated to keep pace with innovation as well as conform to the circular economy.

These investments should lead to multifunctional and safe new materials embedded in strategic value chains, radically reducing environmental footprint, and moving towards a new economic cycle, characterised by a seamless integration of materials science which will enhance the competitiveness of European industries.

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; by exploring their potential for society, the environment and industry and be driven by the relevant SDGs. This purpose-driven exploration will not target specific applications but will focus on the possible effect on the three broad objectives described above.

Success depends on the combination of disciplines, from fundamental research in natural sciences to engineering, manufacturing and computer learning. Furthermore, radically new ideas sometimes emerge through interaction of creative people from very different background, including the civil society. This research and innovation priority will facilitate and stimulate these interactions by providing opportunities to meet, mutually inspire, cooperate and develop together innovative ideas. Social sciences and humanities will also play a role in envisaging the transformation pathways.

Examples of technologies 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). This entails a merging of new characterisation methodologies with modelling, to facilitate the use of artificial intelligence for the efficient design of new materials.

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 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).

These activities will not only finance collaborative research and innovation projects, but also create fora for networking creative people from different backgrounds to inspire innovative ideas, including with citizens. They will also help stakeholders to navigate rapidly changing environments, for instance by actively transferring ideas and technologies between players that would not normally interact, or by combinations of different foresight activities (short-term, long-term, sectorial) to prioritise strategic directions while avoiding narrow visions for the future.

These activities are complementary to Pillar III activities under the EIC. The focus in this cluster is on renewal and transformative potential for business and industry sectors addressed by this cluster; and on fostering new ecosystems of innovation and new value chains. The activities will combine in an agile way the heavy long-term investment on industry-driven priorities with the exploration of new and potentially disruptive technologies.

4.5 Artificial Intelligence and Robotics

Driven by increased computing power, the availability of large amounts of data (the essential raw material for innovation, competiveness 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 and inclusive approach.[113] Europe should strive for a technology leadership position in AI. The EU must also promote the adoption of principles and global standards, as well as actively participate in their development, e.g. through standardisation bodies, which will ensure an ethical approach to the development and use of technologies at both EU and international level.

The objective is to ensure that all citizens will experience the advantages of AI in daily life, such as traffic optimization and autonomous driving to reduce citizens everyday stress and drastically reduce the number of road accidents, to truly intuitive AI-based systems adapting to human needs, to support them in specific tasks, improving their working conditions, and making the technology easy to use by all, even the non-experts in AI. Also society as a whole will benefit from AI-based solutions to optimise the lifecycle of resources (energy, food, etc.), and make it more environmentally and economically sustainable, from production to distribution and use. Medical doctors will be able to ask for the support of powerful data-intensive machine learning to assist their diagnostic and therapy decisions. Firefighters will get the support of robots to approach hazardous intervention zones. Overall, progress in AI and robotics should be fully exploited to continue supporting European industrial competitiveness; and to bring all its potential benefits to the other clusters, to address global challenges, with direct impacts in sectors such as healthcare, agriculture, manufacturing, energy, transport. Its potential for the reduction of environmental footprints should also be fully exploited.

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.

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

The challenges in AI and Robotics (embodied AI, which is one of European strength in AI) include foundational research improving hardware (chips for AI, but also mechatronics, and advanced sensing and actuation for safer, faster, more precise, and more energy efficient robots), algorithms, achieving explainable AI (transparent decision making), adaptive learning, and improving smart, collaborative, safe and efficient robots and autonomous systems. Adaptation to user-requirements to produce user-friendly, robust and effective solutions for their application domains, will also play an important role in acceptance of the technology. Applied research is also needed to advance and demonstrate technological progress, meeting the requirements of applications/sectors needs, but also important to drive longer-term research in identifying new scientific/technological challenges. Common AI platforms, sharing tools and resources for research and innovation in AI, and reinforced collaboration among researchers are expected to combat fragmentation and foster progress more efficiently, strengthening European's position. The support to excellence centres and their networking will structure the community, foster scientific excellence and make Europe attractive for the best scientists in AI. Synergies with Digital Innovation Hubs in robotics and AI will support applied research and help disseminate these technologies.

These investments should lead to significant European advances in AI, characterised by increased societal engagement, human-centred and ethical approaches, fostering acceptance with multidisciplinary approaches and awareness raising through dissemination activities.

4.6 Next Generation Internet

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

The Internet of today has significant limitations. The risk of breaches of security or privacy, lack of accessibility for users with disabilities, lack of user control of their data, and manipulation or disinformation are some of the major challenges to be tackled. Furthermore, the internet economy is vulnerable to concentration of market positions from devices to networks. Concentration in few powerful providers generates potential threats of user lock-in and consumer harm.

Europe has no choice but to invest further in research and innovation to be a leading force in shaping the internet technological and market development in full respect of people's fundamental needs, including trust, security and inclusion.

The next generation Internet (NGI) initiative aims to develop the key technologies and the infrastructures for the Internet of tomorrow. It will develop a human-centric trustworthy internet enabling full connectivity and accessibility, transparent recommendations and collective intelligence (involving people, processes, data, content and things) and promoting core European values.

NGI aims at supporting a competitive European Internet value chain, which can meet the future industrial and societal needs establishing Smart Networks and Services (including Internet of Things and edge computing infrastructures) and Content platforms. The initiative addresses the innovative vertical applications supported by such platforms including through large-scale pilots. It also fosters the use of artificial intelligence along a continuum of novel data infrastructures and services, from cognitive clouds to edge applications.

NGI 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. It relies on an agile eco-system of top European innovators who develop trustworthy internet technologies, including open source components and Universal Design.

Interactive Technologies, including immersive technologies and language technologies, combined with AI, for example in virtual agents or accessibility automation tools, will support the human centric aspects of the Next Generation Internet and allow for a more inclusive, user-oriented/driven and innovative use of computers, machines and the Internet, bringing opportunities in many industrial and societal sectors, helping tackle sustainability challenges and ensuring that benefits of research and innovation are reaped equally by all members of society.

Distributed ledger technologies, being cross-cutting enabling technologies which support efficiency and trust in organising workflows, validation of transactions and operating autonomous systems, can enable the development of EU data spaces while empowering citizens, public services and businesses to control and share access to data.

4.7 Advanced Computing and Big Data

Today, Europe critically depends on foreign supercomputing technologies that are essential 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, keeping in mind environmental standards (e.g. 'Green ICT').

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

Combined with those advances, research and innovation 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 research and innovation 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 etc.) 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. Federation of data, especially while processing sensitive categories of data, such as health data, can contribute to overcoming some of the challenges, thus contributing to the creation of a European Health Data Space.

Furthermore, sustainability issues posed by digital technologies should be addressed through large scale research and innovation activities aiming to reduce the carbon footprint and substantially improve the energy efficiency of ICT processes and technologies, covering hardware, software, sensors, networks, storage and data centers; and to provide metrics and methodologies to measure in a standardised way the carbon footprint and energy efficiency of data processing and transmission chains.

These investments should allow Europe to rely on its own high-performance computing technologies.

4.8 A globally competitive space sector reinforcing EU sovereignty

Research and innovation actions will foster the competitiveness of space systems in particular for ultra-high throughput telecommunication, support the integration of satellites in 5G networks, advanced navigation signals and high-resolution earth observation, supporting in particular the EU space programme components. Digital and automated industrial processes will enable seamless manufacturing for the production of cost effective space systems including constellations. In the mid to long term, the future space ecosystem should include hybrid, smart and reconfigurable satellites, which can 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 for reducing the production and operation cost such as reusability of launcher components, low cost, high thrust and green propulsion, micro launchers, new types of payloads and space routes. Opportunities for

in-orbit validation ("IOV") and in-orbit demonstration ("IOD") will contribute to de-risk new technologies, concepts and applications. These will be operating from modern and flexible launch facilities. In the other hand the development of new space increases the risk of collision between satellites and debris and requires to develop new technologies enabling the development of space traffic management.

EU-funded research will also contribute to critical technologies, space science and missions and outreach and education activities. Development of downstream applications and synergies with non-space sectors, including with advanced enabling technologies such as manufacturing technologies, digital technologies, advanced materials, AI and Robotics, advanced Computing and Big data, will be promoted

The role of quantum technologies in space infrastructure and for space-based services will become more and more important, especially in terms of security, efficiency and reliability and shall therefore be further explored.

These investments should lead to globally flexible, reconfigurable and competitive space systems and services, which can be tailored to evolving customer needs. This will provide the EU space sector with a global competitive edge, contribute to space industry modernisation and foster the development of 'New Space' business eco-systems. This will also contribute to the EU Space Strategy, provide the necessary research and innovation to support the EU's Space Programme, enhance the autonomy of the sector and secure space-related data and services, as well as support the overall effort of the European Union in tackling global challenge through long term programming with measurable objectives and leading to ambitious demonstrations including through co-funded actions where appropriate.

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 Plan[114] 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 secure, sustainable, responsibly-sourced and affordable supply of raw materials, in particular critical raw materials (through substitution, resource efficiency, better recycling and a clean primary production) reduce the dependence on overseas handling and processing of municipal and industrial waste.

[114] COM(2015)0614

4.10 Low-carbon and Clean Industries

Energy-intensive industries have a central role in the EU's industrial value chains and the low-CO_2 Emissions industry has been identified as a strategic value chain[115]. 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 and 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 greenhouses 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, usage of hydrogen, 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. For a broad market diffusion in the medium and long-term, appropriate economic framework conditions allowing companies to deploy these technologies in an economically viable manner need to be created.

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 the 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.

"Hubs for Circularity" should be created as points of industrial (large companies and SMEs) and public facilities within a particular region or a group of municipalities, achieving more circularity and carbon neutrality in their use of resources, while boosting the competitiveness of the EU industry in the global landscape.

The co-programmed partnerships Circular and Climate-neutral Industries and Clean Steel are expected to bring a broad-based approach to these activities, and those related to the circular industries, capturing in particular the full potential of industrial symbiosis.

4.11 New services from Space for the EU society and economy

Research and innovation activities will prepare for the next generation and applications of European Global Navigation Satellite Systems **(Galileo/ EGNOS)** which will provide precise positioning, navigation and timing This will contribute to intelligent mobility, lowering CO2

[115] Report on 'Strengthening Strategic Value Chains for a future-ready EU Industry' by the Strategic Forum on Important Projects of Common European Interest (IPCEI) high-level expert group set up by the European Commission in March 2018, available at: https://ec.europa.eu/docsroom/documents/37824

emissions, connectivity and infrastructures, whilst ensuring a non-dependent and sustainable supply chain, and integration with other technologies such as 5G.

Research and innovation activities should support core services of the European Union Earth Observation System **(Copernicus)** to enhance these and develop new service elements or products, thematic cross-cutting applications and high-quality, well-validated and easy-to-use products and information to respond to different user communities for a European and global uptake, in areas such as climate mitigation, monitoring GHG, environment, including Arctic regions, agriculture and urban planning, security. These will rely on innovative and evolutionary data and information infrastructures and services.

Further developments in sensors technologies and data processing will be supported as well as new services for Space Surveillance and Tracking (SST) and research on space traffic management, 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)**.

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

The potential of the downstream segment of the space sector is not yet fully exploited, in particular with EGNSS and Copernicus. Key applications such as Galileo secure real-time high-accuracy positioning for automated transport, Copernicus earth observation on polar research and natural disasters, services for environmental monitoring systems, migration, agriculture can help tackle global challenges, create high-skilled jobs and open up new market opportunities for businesses. Synergies between Galileo/Copernicus will be reinforced and the availability of space assets and data from other organizations (e.g. EUMETSAT, ESA) better exploited.

These investments will provide EU citizens, companies and public authorities with a wealth of downstream applications benefitting from more accurate positioning &navigation services, higher resolution earth observations that will cater for digitalized mobility, climate and environment as well as more efficient and new emergency and security services.

The objectives stated under this section and under section 4.8 A globally competitive space sector reinforcing EU sovereignty will be pursued jointly with the European Agency for Space Programme (currently GSA), in close coordination with the European Space Agency and national space programmes, in mutually supportive and complementary approach. The development of Strategic Research and Innovation Agenda will be encouraged (e.g. on competitiveness of the space sector and access to space) together with the emergence of a coherent overall agenda that can answer the challenges of the future single Space Programme. Actions favouring openness and widening to new actors in space (e.g. New Space) will be considered, which have the potential to open up new possibilities in Europe. The framework to support space education and public engagement to attract young talents and provide appropriate skills will also be investigated.

5. International Cooperation

- Activities under this cluster will engage with international partners as appropriate to enhance exchange of know-how, access to international value chains, in areas of mutual benefit and EU interest, and with due consideration to the technological sovereignty/autonomy objective. Particular attention will be paid to Europe's strong position in sustainability, to promote EU climate-neutral, clean and circular technologies. Activities will also aim to pursue level playing fields, reciprocity and the development of technologies that put human rights and social values first, including through industrial and policy dialogues. Examples include: Materials safety methodologies and standards, aiming at harmonised approaches, e.g. for nanosafety and safe-by-design.
- Circular economy and climate-neutral technologies, to support global sustainability and European industry, including a harmonised approach to materials life cycle assessment ("circularity by design").
- Common standards and interoperability, including in the regulatory context of manufacturing technologies, digital technologies and Artificial Intelligence (focussed on ethics and data);
- On Space, dialogues are held on a regular basis with a number of countries. Copernicus has developed a number of agreements for mutual data exchange and promotes cooperation with Framework Programme Topics with these international cooperation partners.

6. 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.

The following areas for possible future partnerships with a lead under this cluster have been identified:

- Made in Europe (co-programmed)
- Key Digital Technologies (possible institutionalised Partnership based on Article 187 TFEU)
- Photonics (co-programmed)
- Artificial Intelligence, data and robotics (co-programmed)
- Smart networks and Services (possible institutionalised Partnership based on Article 187 TFEU)
- HPC (possible institutionalised Partnership based on Article 187 TFEU)
- Circular and Climate-neutral industries (co-programmed)
- Clean Steel (co-programmed)
- Metrology (possible institutionalised Partnership based on Article 185 TFEU) – also relevant for clusters 1, 3, 5, and 6
- Globally Competitive Space Systems (co-programmed)

In addition, a candidate European Partnership on a Geological Service for Europe would contribute to this cluster in terms of improving the knowledge base and surface data on the availability of raw materials.

A partnership approach for the proposed priorities would be more effective compared to traditional 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. Partnerships, in particular those impacting climate change, should also be able to reach out at international level.

Activities within the Cluster "Digital, Industry and Space" will also be closely related and collaborate with relevant EIT KICs, notably EIT Raw materials, EIT Manufacturing and EIT Digital.

7. Missions

Depending on the scope of future specific Missions, activities within the Cluster Digital Industry and Space might be particularly relevant to the Mission(s) identified within the "Climate Adaptation including Societal Transformation", "Cancer" and the "Climate-Neutral and Smart Cities" mission areas, as well as other mission areas.

ANNEX 5 - CLUSTER 5: CLIMATE, ENERGY AND MOBILITY

1. Global Challenges and Their Drivers

The main objectives of this cluster are to foster climate action, 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 any possible environmental, social or economic rebound effects). The overarching driver is the ambition to achieve climate neutrality in Europe by 2050, entailing decarbonisation of the energy, transport and other sectors by 2050 at the latest, while, at the same time, ensuring the security of energy supply and boosting the sectors' competitiveness. This is crucial as both sectors represent an important share of the GDP and jobs in Europe, the transformation of these sectors offers tremendous business opportunities on a global scale and the energy and transport services 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. To these ends, Europe follows the "energy-efficiency-first" principle. Actions will support the implementation of the Paris Agreement, the European Green Deal to reach Climate Neutrality by 2050 (and a greater level of ambition by 2030) and EU policy priorities in the areas of climate, energy, and mobility, 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 2016[116], so decoupling their environmental impacts from economic growth and achieving deep decarbonisation of these sectors is crucial. As foreseen by the European Commission's strategic vision "A Clean Planet for All"[117], 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 strategic vision[118] for achieving net-zero greenhouse gas emissions by 2050. The long-term strategic vision 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. Commission President von der Leyen emphasised the commitment of the EU by announcing the ambition for the EU to become the world's first climate-neutral region by 2050.

Research and Innovation will heavily influence the speed at which this transition can take place, directly affecting the associated costs, impacts and co-benefits, such as better air quality, increased employment, social inclusion, sustainable resource management (including biodiversity), and reduced dependency on fossil fuels. Beyond the inevitable social transitions and lifestyle changes, a key contribution to success is the development of a wide portfolio of – from a life-cycle

[116] https://ec.europa.eu/eurostat/statistics-explained/pdfscache/1180.pdf
[117] COM(2018) 773 final, A Clean Planet for all
[118] COM(2018) 773 final, A Clean Planet for all

perspective – cost-effective carbon-free alternatives for each GHG-emitting activity, based on often in combination with enhanced sector coupling, digitalisation and system integration. The rate at which European research and innovation actions succeed in developing, upscaling, implementing, and commercialising such innovative solutions will steer EU's future competitiveness of its existing and newly emerging industries.

In the medium term, EU legislation under 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 levels[119] – in a cost-efficient way, including the EU Emission Trading Scheme 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 and solutions to market readiness and feed the innovation cycle with discoveries that may lead to disruptive solutions (including shift in user behaviour) 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 research and innovation 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 SDGs, 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. Targeted impacts

The long term targeted impact of this cluster corresponds directly to the main objectives of fostering climate action while at the same time improving the sustainability, security and competitiveness of the energy and transport industry as well as the quality of the services that these sectors bring to citizens and society at large. Actions will aim to provide the basis for systemic change as well as shaping the necessary technological, industrial economic and societal transformations to achieve climate neutrality in an inclusive and socially fair way, and to contribute to creating more and better jobs thus helping people to embrace the systemic transformation.

The strategic plan focuses on targeted impacts across the various parts of the cluster. These include:

- Achieving an advanced knowledge base in climate science that can guide the development of required policy measures and low-and zero-carbon technologies essential to catalyse the transition to a climate-neutral emissions economy and society and for adaptation to the unavoidable climate change impacts.
- New cross-sectoral energy/transport solutions enabling both the clean and sustainable energy transition and the decarbonisation of transport.
- Achieve cleaner, more efficient, more secure and competitive energy supply, notably by boosting cost performance and reliability of renewable energy solutions and by making the energy grid more flexible and secure.

[119] 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.

- Support cleaner, safer, affordable and sustainable energy demand side solutions for all users, ensuring a just transition towards fully decarbonised, more energy efficient and renewable energy system reducing any negative impacts, and European dependency on energy import.
- Significantly contribute to net-zero greenhouse gas emissions and reduced air pollutants in and across all transport modes protecting human health and achieving at the same time strengthened global competitiveness of the European transport sector, through the development and usage of new technological solutions in all transport modes.
- New, affordable smart, inclusive and sustainable mobility services which will result in significant safety, environmental, health, economic and social benefits such as reduced accidents, decreased congestion, reduced energy consumption and emissions of vehicles, increased efficiency and productivity of transport operations, improved working conditions and the creation of new jobs.
- Help people to embrace the systemic transformation

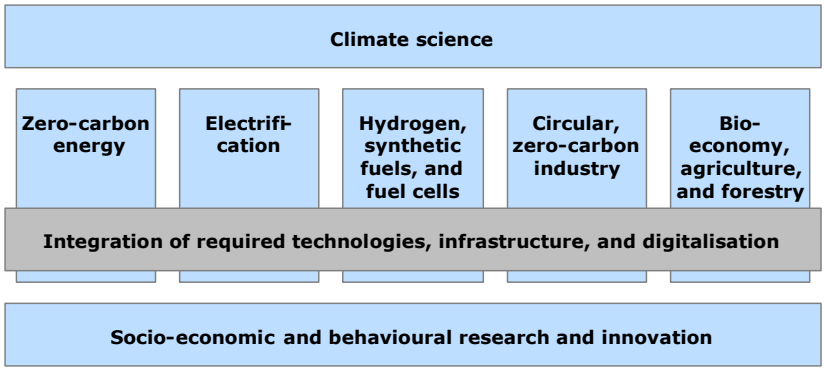
The desired impacts are further specified in the following section in relation to each priority.

4. Key Research and Innovation Orientations

The energy and mobility sectors are closely interlinked and face many common challenges. An integrated, systemic approach is needed to maximise synergies and cross-fertilisation across these and any other relevant sectors. For example, research and innovation actions aiming at reducing cost for hydrogen generation and at increasing battery capacity – thereby fostering competitive European value chains – would bring pivotal change benefiting the clean energy transition and the decarbonisation of transport and industry. Similarly, an integrated approach, is essential to make urban ecosystems more efficient and clean, thus improving the quality of life and health of citizens in cities and communities. Cross-fertilisation between different industries and programs (such as EU navigation and earth observation programs, e.g. EGNOS, Galileo) can also lead to the emergence of new solutions to support the efficient transition to a net-zero greenhouse gas emissions economy.

Figure 3 illustrates the need to not only develop a wide range of advanced low and zero carbon technologies, but to organise research and innovation activities from a system perspective, by working on solutions (e.g. electrification, energy efficiency, capture of renewable energy and 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 system in all its demand side domains, especially the transport system and the built environment. In addition, climate resilience and climate proofing of infrastructure, as well as a full value chain circularity approach, help the EU with climate change adaptation while protecting the planet resources as a whole. Moreover, there is a need to optimise research and innovation activities from a value chain perspective, to support the circular economy and to reduce environmental footprint and pollution arising from different stages.

Relevant research and innovation areas for decarbonisation



To address the research and innovation challenges in the context of decarbonising the EU's economy and go for a full circular 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:

4.1 Advance climate science and solutions for a climate neutral and resilient society

Challenge: The efficient transition to a net-zero greenhouse gas emissions economy resilient to the impacts of climate change requires profound knowledge in various fields of research. Advancing climate science and creating a knowledge base to inform societal and social transition and to guide the development of policy measures, low-, zero-, and carbon negative technologies, as well as other solutions. It will also look at their application by people, businesses and policymakers at all levels. It is essential that research into solutions contributes to actual deployment of actions and policies (in both mitigation and adaptation). Interactions with other parts of Horizon Europe, and other programmes, are therefore essential.

Europe has been at the forefront of climate science and has to continue to deliver the knowledge to enable efficient decarbonisation pathways.

Targeted 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 knowledge of technological and nature-based solutions for short-to-medium and long-term adaptation and mitigation. 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 topics[120]:

- Produce state of the art science on climate change and on its impacts, how to adapt to it and how to mitigate climate change;
- Build a user-driven knowledge base that comprehensively informs human response to global change;
- Design cost-effective resilient net-zero greenhouse gas emission pathways compatible with a sustainable long-term transition and the Paris Agreement goals;
- Spearhead the development of climate services and decision-support tools and methodologies at local, regional, national and global levels, and evaluate adaptive capacities and limits;
- Further study the interactions, between climate change and biodiversity;
- Incorporate and further advance research in social science and humanities, behavioural science methodologies, integrated assessment modelling, expertise to assess impacts, distributional and spatial effects and a just transition.

Implementation:

Potential research challenges and topics will be addressed through collaborative research and innovation actions, with international cooperation wherever needed.

Since climate action is mainstreamed across Horizon Europe, actions specifically related to climate science and solutions should target challenges that cannot be addressed adequately elsewhere. Therefore, there should be synergies within Horizon Europe and with other programmes to ensure the knowledge generated by climate science research are tested and implemented across sectors (including activities in Pillar I, and other cluster activities in Pillar II, as well as Missions), at all levels of the innovation chain including facilitating market uptake (namely activities in Pillar III).

Links to other parts of Horizon Europe dealing with Industry, Copernicus and Earth Observation (Clusters 4 and 6); Biodiversity, Oceans, Agriculture, forestry, Water and food systems (Cluster 6

[120] For all research and innovation areas, the planned activities should not be considered as comprehensive nor limitative

and Mission areas on Soils and Oceans); cities (including Mission area on Cities), health (Cluster 1) and just transition (cluster 2) need to be systematically taken into account. In the context of Digital Europe, European High Performance Computing infrastructure (EuroHPC), cloud computing, artificial intelligence techniques and the combination of increasingly varied data sets, can be enablers for developing the next generation of climate models (see Advanced Computing and Big Data) and precise and holistic digital simulations of Planet Earth.

4.2 Cross-sectoral solutions for decarbonisation

The energy sector and the two main sectors of energy use in cities and communities (housing and mobility) are closely interlinked and face many common challenges. Citizens' support and involvement is central for achieving the transformation to a decarbonised sustainable and inclusive society. Furthermore we need an integrated approach to maximise synergies and cross-fertilisation across all sectors. Such approach is essential for 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.

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 short-distance waterborne transport, a switch to battery and hybrid propulsion would enable decarbonisation and a reduction in harmful emissions. We also need to assess the potential for long-term solutions for maritime transport and aviation. In the power sector batteries can enable very high shares of intermittent renewable energy technologies. More widely in the industry, batteries can deliver various energy services.

Targeted impact: There is an urgent need for the EU to invest in the development of future battery technologies that are essential to sustain a competitive and sustainable EU battery value chain. To support the development of a world-class European research and innovation eco-system on batteries, by advancing the state of the art of battery technology in terms of material availability and circularity, cost, performance, energy density, safety, user convenience, speed charging and environmental footprint along the value chain and according to sectorial needs, 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 design (with a view to full sustainability including re-use, scarcity of materials and recycling), cell manufacturing and cover for mobile, stationary and possibly other sectorial applications. Research topics such as innovative materials, discovery and engineering of new battery chemistries, smart batteries with sensing and self-healing functionalities, advanced cell manufacturing, circular economy and recycling (cluster 4), batteries, battery management systems, 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 solutions[121] should be included. Research should integrate the full potential contribution of digital technologies.

Implementation: In order to develop a coherent, cross-cluster and strategic battery research programme, and enhance leverage and industrialisation of research results, it is proposed that this strategic research and innovation area is developed through a co-programmed partnership with industrial players and the research community. Strong coordination/cooperation with other relevant partnerships will be essential. International cooperation is key to improving the worldwide sustainability of the entire batteries value chain.

[121] Preparatory actions on future battery technologies supported under the FET Flagships part of Horizon 2020 will feed the Strategic Planning process under Horizon Europe and inform the work on e.g. the proposed partnership Batteries: Towards a competitive European industrial battery value chain (see Annex 7).

4.2.2 Strengthen the European value chain for near-zero 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.

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

Potential research challenges:

- Near-zero carbon hydrogen production pathways, particularly renewable based, and including energy system integration aspects.
- Development of infrastructure for safe, cost- and energy-efficient transport, storage and provision of hydrogen and hydrogen-rich energy carriers, incl. long–term, large-scale storage of hydrogen as energy buffer.
- Demand side technologies 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 waterborne[122].
- Life-cycle analysis for the design of low-emission, energy- and resource-efficient hydrogen supply chains.

Implementation: Building on the existing Joint Undertaking, it is proposed that this strategic research and innovation area is implemented through a European Partnership (possible institutionalised Partnership based on Article 187 TFEU), 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, and supported by bi-lateral international cooperation where appropriate. 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, sustainable and carbon-free built environment , supported through user-friendly and secure digital services, able to adapt to climate change and to increase quality of living. Co-design and co-creation approaches with- and for society can help ensure uptake and deployment of solutions.

Targeted 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 and operating models, financing issues, public sector innovation, incentive structures and social innovation) Improve air and water quality, resilience of energy supply, intelligent mobility services and logistics, liveability and accessibility of cities, public health, comfortable, affordable zero emissions housing as well as the exploitation of relevant European technologies and knowledge.

Potential research challenges:

[122] Hydrogen applications in aviation will be addressed separately in research and innovation related to aviation

- City/district management systems for energy, mobility, water and waste systems 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, zero carbon accessible, inclusive and safe mobility, services and logistics, sustainable and carbon-free housing, built environment, and their impact on energy consumption and resources, urban social innovation, cities' and communities circular and regenerative capacity,
- New governing and financial models to support historic/existing districts regeneration through adaptive reuse of buildings and infrastructures,
- Reducing life-cycle environmental footprint and pollution in cities through nature-based solutions and circular material and equipment,
- Urban land use and integrated planning, including governance and public sector innovation, urban policies, decision-making tools, new models for citizen participation;
- Next generation scalable interoperable digital infrastructure and software solutions for innovative services across different urban sectors (energy, mobility, buildings, water and sewage, urban planning, etc.), fuelled by latest information and communication (ICT) (like 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 research and innovation actions, and/or as part of other Clusters and cross-cluster Horizon Europe Mission research and innovation in the area of 'Climate-Neutral and Smart Cities' and/or in relevant partnerships. Additional synergies will be examined with other EC-funded projects with large stakeholder platforms and co-programmed partnerships. International cooperation can be pursued with third countries and regions with an expanding market for sustainable technologies.

4.2.4 Empowering citizens to engage in the transformation to a decarbonised society

Challenge: Societal transformation is embedded in broader societal needs and hence depends crucially on the buy-in of citizens, beyond technological aspects. Finding new and better ways to involve Europe's citizens in the low-carbon transition and in the sustainable economy, in the design / implementation of the policy measures, and for creating win-win situations for consumers and producers, network providers and investors is therefore of critical importance.

Targeted impact: Reduced energy consumption and related emissions in all stages of the energy, housing and transport sector. More involved citizens will help devise novel and original business models and facilitate sustainable finance. Socio-economic research can provide analysis and recommendations for effectively engaging and empowering citizens to participate in the clean energy transition, from planning to decision-making and implementation. Research results can also inform transition strategies of regions. This will facilitate the transformation to a decarbonised society, in line with the EU's 2050 climate targets.

Potential research challenges:

- Develop technologies, services and business models for enhancing decision-making in home life and working life. This includes increasing 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 production and use, as well as resource flows.
- Develop and enhance methods of citizen's engagement in long-term energy, and transport investment planning and transition policies. Develop new participatory models to engage citizens in investments.
- 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 transition to a decarbonised society.

- Further elaborate Contribute to the Initiative of Coal Regions in Transition from a research and innovation perspective, enabling regions to identify and respond to their unique contexts and opportunities[123].

Implementation: Potential research challenges and topics will be addressed via collaborative research and innovation, including citizen-science/user-led innovation approaches. A close cooperation with materials for energy, built environment and city related research and innovation 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. International cooperation can be pursued with third countries and regions where advanced EU approaches can support implementing climate mitigation objectives.

4.2.5 Foster emerging breakthrough technologies and climate solutions

Challenge: Although the contribution of a wide range of technologies to decarbonisation is already foreseeable, EU research and innovation programming should also leave room for unanticipated emerging and break-through technologies with a high potential for decarbonisation. Research and innovation in this area may be technological in nature but needs to be accompanied with assessment of environmental impact, social and economic impacts, measures to mitigate them and, and possible regulatory needs. Examples of such cases may be in the areas of: direct conversion of solar energy to synthetize fuels and artificial photosynthesis; solar-driven chemistry, direct air CO_2 capture and storage (DACCS) and re-use; methane capture / cracking for blue hydrogen; sustainable production of ~~various~~ synthetic fuels from renewable energy; disruptive transport technologies, etc.

Targeted 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 research and innovation 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 emissions 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. Research and innovation actions will contribute to making 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 should be further investigated. To reduce CO_2 emissions from the power and energy-intensive industry sector, environmentally sound solutions for capturing, utilisation and storage of CO_2 (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) for its 10 Key Actions[124].

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.

[123] This does not entail activities aimed at the continuation of fossil fuel based energy

[124] https://setis.ec.europa.eu/actions-towards-implementing-integrated-set-plan/implementation-plans

Renewable fuels, including synthetic and biofuels, provide long-term solutions for the transport and energy-intensive industry sectors, in particular for applications where fuels with high energy density or very large fuel quantities are required to reduce the carbon footprint of these sectors.

Targeted 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 ~~and life-cycle costs~~ (from cradle to cradle) 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, including transport and energy-intensive industries;
- 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 and through the development of integrated bio-refineries.

Implementation: Potential research challenges and topics will be addressed through collaborative research and innovation 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 and bi-lateral cooperation with strategic partner countries).

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 higher shares of variable renewable energy and to appropriately monitor their availability (at all voltage levels). Exploiting synergies between different electricity, heating and cooling networks, gas networks, transport infrastructure and digital infrastructure will be crucial for enabling the smart, integrated, flexible and green operation of the relevant infrastructures.

Targeted 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 local energy 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, green and cyber-secure energy system, relying also on EU-specific technologies ;

- Develop/demonstrate solutions to adapt the 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 research and innovation actions. Leveraging more investments and a better coordination with national funding programmes may require a partnership approach. International cooperation will be pursued where relevant, both with other technology leaders (in particular through the Mission Innovation initiative) and with countries/regions with expanding markets for advanced sustainable energy system technologies.

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 CO_2 emission abatement option that holds great potential for the power sector and especially for industries with high process emissions. It is also an important technology that allows the production of large volumes of near-zero carbon ('blue') hydrogen and other synthetic fuels from natural gas until sufficient renewable ('green') hydrogen and synthetic fuels becomes available.

Targeted impact: To accelerate the development of CCUS as a CO_2 emission mitigation option in electricity generation and industry applications. This includes CCS in combination with sustainable bioenergy (BECCS) which, combined with appropriate land use, can result in 'negative' CO_2 emissions. It can also address the conversion of CO_2 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);
- Strategies and feasibility studies for the development of CCUS hubs and clusters, including strategies for CO2-transport and CO2-infrastructures, addressing both technology and regulation aspects;
- Improving the CO_2 balance and energy performance of CO_2 conversion to value-added products;

Implementation: Potential research challenges and topics will be addressed through collaborative research and innovation 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).[125] More than 50% of our energy use is thermal energy. Therefore, thermal energy

storage enables a higher utilization of variable renewable sources (direct solar or geothermal heat) in the heating and cooling sector.

Targeted 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 alternative storage technologies;
- Demonstrate the integration of different energy storage technologies in specific hybrid solutions and their integration in the grid;

Implementation: Potential research challenges and topics will be addressed via collaborative research and innovation. Actions will be developed in complementarity with other areas addressed in this cluster. International cooperation will be pursued where relevant, both with other technology leaders and with countries/regions with expanding markets for advanced energy storage systems and technologies.

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 research and innovation agendas in dedicated areas stimulating Member States to coordinate national programmes and to pool funding across borders. Given the scale of the research and innovation investments needed, this leverage effect on public and private funding towards joint research and innovation 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.

Targeted impact: Leverage public and private funding towards joint research and innovation 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 research and innovation 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 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.

4.4.1 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 CO_2 emissions in the EU[126]. Enabling cost-effective energy renovation of buildings, including built heritage, is a top research and innovation objective for the EU which can lead to significant energy savings and better life-cycle resource efficiency, including whole life carbon. This, together with enhanced interactions of buildings with the energy system and between buildings, opens up a significant decarbonisation and employment potential.

Targeted 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, bearing in mind user needs and the need to move towards climate neutrality in the longer term as well as to limit whole life carbon as well as other life-cycle environmental impacts of buildings.

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, including 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 and financing models, costs & affordability, safety, accessibility, user needs, behaviour and acceptance);
- Life cycle approaches integrating resource efficiency, circular economy and environmental impacts (e.g. biodiversity, natural resource depletion, materials, carbon footprint).

Implementation: Potential research challenges and topics will be addressed through collaborative research and innovation 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'.

4.4.2 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 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.

[126] Looking at the full life cycle of buildings, the energy consumption is about 50%, as is the share of EU CO2 emissions.

Targeted 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 including ports 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 research and innovation. To ensure complementarity across different parts of Horizon Europe, these will be addressed through, or in close cooperation with, industry-related research and innovation 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 staff[127]. 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 CO_2 emissions and remains dependent on oil for 92% of its energy demand. Furthermore, despite significant technological progress over past decades, current and 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 research and innovation 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 research and innovation 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 research and innovation 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 and affordable system services into the transport system .

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

Potential research challenges and topics: This priority will address both 1) clean road vehicles technologies (lightweight materials, drive trains, brakes, tyres, 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 affordable 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.

[127] "Towards clean, competitive and connected mobility: the contribution of transport research and Innovation to the Mobility Package" SWD (2017) 223 final

Implementation: In order to develop a coherent and strategic research and innovation programme, and enhance leverage and industrialisation, it is proposed that this strategic research and innovation 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.

Targeted 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, leveraging EU satellite navigation / positioning technologies.

Implementation: Building on the successful operation of the existing Joint Undertaking, potential research challenges and topics will be addressed via a possible institutionalised Partnership based on Article 187 TFEU and /collaborative research.

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, in fuel efficiency per passenger-km 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. Beyond CO2 emissions, aviation is responsible for the creation of contrails and non-CO2 emissions, which also exhibit radiative forcing. In addition, air pollution and noise levels need to be addressed. Research and innovation 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

Targeted impact: To pave the way towards a transformative clean aviation. To strengthen European aero-industry collaboration and maintain a global leadership position. To develop innovative, cutting edge research and innovation projects accelerating the reduction of all aviation impacts and emissions (CO_2 and non-CO_2, including manufacturing and end-of-life, noise). To develop enabling and integrated aircraft technologies for deep decarbonisation transformation, as well as enable and promote the use of sustainable aviation fuels.

The research and innovation activities will be based on a transformative decarbonisation roadmap that encompasses impactful solutions for different platforms at appropriate time frames in line with the transition to a climate neutral economy by 2050. It is envisaged that new technologies will provide for a substantial fuel efficiency improvement for next generation aircraft technology, a substantial decrease in aviation non-CO_2 emissions and major progress towards cost-competitive sustainable alternative fuels[128].

Potential research challenges:

- Research new aircraft configurations and new propulsion systems towards substantially enhanced GHG performance and fuel efficiency for the next generation of commercial aircraft technology. Accelerate the electrification of aviation;
- Develop and demonstrate solutions that reduce the impact of non-CO_2 emissions on climate and environment, while considering the interdependencies with CO2 emissions;
- Develop solutions to accelerate the introduction of sustainable low carbon fuels (including synthetic fuels, hydrogen);
- Deliver ecological and cost-efficient manufacturing, and end-of-life procedures;

[128] Measurable key performance indicators to be defined.

- 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 though a dedicated European Partnership, possibly as institutionalised Partnership based on Article 187 TFEU, 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

Targeted 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), leveraging EU satellite navigation / positioning technologies.
- 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 a possible institutionalised Partnership based on Article 187 TFEU.

4.5.4 Enable low-carbon, smart, 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 emissions[129]. 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.

Targeted impact: Accelerate the development and prepare the deployment of low-carbon and clean solution in the shipping sector, improve its system efficiency, enhancing digital and EU satellite-navigation solutions and contribute to the competitiveness of the European waterborne sector. Reduce environmental impact (on biodiversity, noise, pollution and waste management).

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, and/or operations
- Automation and digitalisation in maritime;
- Research and innovation in Ports: alternate fuel and electricity supplies and uses, floating ports, capacity management and sustainability in context of mega ships, logistic chains, port-city opportunities and integration of water freight and passenger solutions in spatial planning;

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

- 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 research and innovation and / or a partnership.

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 research and innovation activities to develop appropriate solutions. Furthermore, possible new health-related challenges need to be monitored and investigated.

Targeted 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;
- Develop/demonstrate solutions for the mitigation of these negative effects adapted to each specific aspect; quality of life and wellbeing of passengers and citizens;
- 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; methods and tools to incentivise a change in citizen behaviour.

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

4.6 Develop seamless, smart, safe, accessible and inclusive 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, and advanced satellite navigation services (Galileo/EGNOS) 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, creating new jobs and contributing to social cohesion. To succeed in this transformation, Europe's ageing (and not always sustainable) 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. To maximise societal, environmental and economic benefits, in addition to technological solutions, it is essential to address human and social aspects such as: analysis of mobility factors and patterns, representations of different social groups and inclusiveness of new solutions, capacity building and public acceptance, etc.

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"[130] and support the development and deployment of connected and automated, fully accessible mobility technologies, services and infrastructure.

Targeted 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 (allowing for personal mobility while reducing overall environmental impact).

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 EU satellite navigation/ positioning technologies, data-processing, artificial intelligence and connectivity, ethics, privacy, safety, security and cybersecurity accessibility liability, user and public acceptance, governance and international cooperation;
- Societal and environmental impacts of the automated road transport system (economic, environmental, social, training, qualifications, 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 European Partnership (possibly institutionalised Partnership based on Article 187 TFEU), 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. Anticipating climate change is crucial for developing new types of innovative transport infrastructure for 2050, with an increasing challenge on its resilience and its environmental impact. Moreover, focusing on new transport modes and usages is a key to improve inter-modality and therefore improve the competitiveness and the quality of the services.

Targeted 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 infrastructure maintenance and upgrade, with a view to improving safety, climate resilience and environmental impact (incl. habitat and biodiversity) 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 including aspects of cybersecurity;
- 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;

[130] COM (2018) 283

- 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 research and innovation.

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.

Targeted 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 digital technological solutions and 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)
- Data sharing issues: exchange models and data use by different public / private stakeholders, need for common approaches, and/or rules and regulations;
- Traffic optimisation of conventional, (semi-) automated and unmanned vehicles within a multi-modal NTM system.
- Enabling EU-wide co-modal freight transport services connected to global supply chains within a well synchronised, smart and seamless network.
- Inclusion of provisions for soft / active mobility (bikes + walking).

Implementation: Potential research challenges and topics will be addressed via collaborative research and innovation.

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.

Targeted 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, smart public transport and sustainable mobility services in all modes in rural and urban areas.

Potential research challenges and topics:

- New digital infrastructures and their interconnectivity and interoperability also with EU satellite navigation, 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 digital technologies and EU satellite navigation services, 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, digital, 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 research and innovation, in collaboration with cluster 'Digital, Industry and Space' and with Cluster 'Food, Bioeconomy, Natural Resources, Agriculture and Environment'.

4.6.5 Increase transport safety – per mode and across modes

Challenge: Safety is of primary concern for any transport system and the EU set ambitious targets in its 2011 Transport White Paper. Research and innovation will underpin the three pillars affecting safety - technologies, regulations and human factors (individual and organisational aspects, including interaction with automation). The approach will be risk-based and systemic, including transport means/vehicles, infrastructure (e.g. train stations, airports, and ports), the physical environment (e.g. weather) and the various actors (e.g. manufacturers, regulators, operators, users) as well as all their interfaces. Specific issues per transport mode and synergies across modes will be addressed, in particular for safety culture, data-exploitation and safety/cyber-security interaction. Specific consideration will be given to high consequence low frequency events (such as passenger ship accidents) and emergency issues requiring fast-track research to accelerate safety assurance. Synergies will be exploited across research at national, EU and international level together with national authorities, EU agencies and international organisations to improve rulemaking, safety promotion and oversight.

Targeted impact: Contribute to drastically reduce accidents and incidents, fatalities, injuries and environmental damage 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:

- Building, analysing and sharing safety data and safety intelligence;
- Understanding and predictive assessment of safety risks for design, operations and system effectiveness;
- Human factors, including societal behaviours, new mobility patterns, perception of information, situational awareness and interaction with automation;
- Smooth interaction between all users, their vehicles, infrastructure and physical environment in a safe system approach;
- New technologies and safety solutions, considering emerging risks and enablers (e.g. artificial intelligence);
- Improved preparation, validation, monitoring and enforcement of safety regulations, rules, standards, safety management systems and training, exploring potential of EU space technologies;
- Accident management and rapid response;

Implementation: Potential research challenges and topics will be addressed via collaborative research and innovation.

Overview of links between intervention areas (HE SP) and strategic research and innovation areas of the Strategic Plan document
X – strong link, **o** – link (less strong as for '**X'**)

Intervention areas as in Horizon Europe legal base / Strategic research and Innovation areas	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
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	X	o	o	X		X
Hydrogen		X	o	o		o	X		X
Communities and cities	o	o	X	X	X		X	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	0				o		X		

Develop seamless, smart, and safe mobility systems									
Mobility and Safety for Automated Road Transport					o	X		X	
Competitive and innovative transport infrastructure			o	X		X		X	
Future transport network and integrated traffic management		o	o		o	X		X	
Multimodal freight logistics and passenger mobility services			o		o	X		X	
Transport safety across modes						X	X	X	o

5. International cooperation

International cooperation is crucial to ensure access to talent, knowledge, know-how, facilities and markets worldwide, to effectively tackle global challenges, to implement global commitments and to ensure global standards, inter-operability and a level playing field. Cooperation with third countries and international organisations/initiatives will be based on common interest, mutual benefit and global commitments to implement the Paris Agreement and the SDGs. This will strengthen the EU's research and innovation excellence, attractiveness and economic and industrial competitiveness, contribute to tackle global challenges, and to support the Union's external policies.

The EU intends to play an increasingly leading role in global/multilateral initiatives and/or organisations (e.g. Mission Innovation, Clean Energy Ministerial, IEA, IRENA, IPCC, GEO, United Nations' agencies as the International Civil Aviation Organisation, International Maritime Organisation) and maintain technological leadership in critical technology areas. The EU plans to develop its bilateral/multilateral and bi-regional/multi-regional research and innovation cooperation with strategic partners who can positively contribute to the EU's excellence in research and innovation or that represent promising markets for advanced European technologies. Particular attention will be paid to international research and innovation cooperation which will support countries to implement effective climate mitigation strategies in line with their commitments under the Paris Agreement, as well as adaptation strategies, in particular in developing countries. The EU will cooperate with international partners on innovative solutions for resource efficient personal and freight transport that respects the environment. This includes integrated, safe and inclusive mobility solutions for cities that will accelerate the transition to climate neutrality. The EU plans to further develop the African Union-European Union Research and Innovation Partnership on Climate Change and Sustainable Energy (CCSE), to continue research and innovation cooperation with its neighbourhood countries and with strategic and like-minded partners in the Americas and Asia, in the frame of its energy, transport and research and innovation dialogues, and Connectivity partnerships.

6. European Partnerships

A partnership approach is used in case it will more effectively achieve objectives and targeted 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.

The following possible areas for future partnerships with a lead under this cluster have been identified:

- **Transforming Europe's rail system**: The proposed partnership would build upon the results achieved by Shift to Rail (S2R) Joint Undertaking (JU) under Horizon 2020, and has the objective of strengthening the role of rail in the transport system (by increasing the

capacity, cost-efficiency and reliability of EU rail services) and reinforcing the global technological leadership of the European rail industry. A Partnership approach is needed in this area because of the high degree of fragmentation of the railway ecosystems, the rail subsystems and the rail innovation life cycle. The proposed Partnership will focus its scope on a limited number of priorities to address emerging challenges, such as automation, digitalisation, decarbonisation and the need to increase the attractiveness of rail freight and its integration into digital multimodal mobility and logistics chains.

- **Integrated Air Traffic Management**: The proposed Partnership has the objective of developing an interoperable and harmonised EU air traffic management (ATM) system based on interoperable technological and operational solutions that foster sustainable air transport and connectivity within Europe and globally. A Partnership approach is warranted because EU intervention to modernise the ATM infrastructure at network level has, so far, been economically more effective and efficient compared to fragmented, local initiatives. The proposed Partnership will build on the Single European Sky Air Traffic Management Research (SESAR) Joint Undertaking (SESAR JU) under Horizon 2020.
- **Clean Aviation**: The primary objective is to contribute to deep decarbonisation of aviation, contributing to the EU's climate and energy goals in-line with the Paris Agreement. It also aims to support industrial policy objectives, by creating sustainable jobs in the EU, while also ensuring safety, security, and EU aviation global leadership, where EU support leads to additionality. A Partnership approach is needed because aviation research needs a coherent and holistic ecosystem approach, with a clear EU leadership, encompassing aircraft technologies, but also new business models, maintenance, operations and services. Furthermore, no single country or private company in Europe has the financial, technological, and human resources to take the technological and financial risk for an ambitious and transformative deep decarbonisation aviation research and innovation path on its own. The Partnership will help to manage the technological and financial risks and will seek synergies with other European Partnerships (e.g. key digital technologies, batteries, clean hydrogen and air-traffic management).
- **Clean Hydrogen:** The overall objective of the initiative is to create a strong, innovative and competitive European Clean Hydrogen sector, fully capable of underpinning the European energy transition by accelerating the market entry of nearly-zero carbon hydrogen-based technologies and delivering a wide range of socio-economic benefits to the European society. A Partnership approach is needed because the hydrogen and fuel cell stakeholder landscape is still extremely fragmented while massive investments are needed which exceed the capabilities of any single actor and requires a credible long-term commitment. The proposed Partnership will build on the existing Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU), but would significantly revise its scope and expand partners (involve more energy companies, waterborne and rail transport, as well as industry, and civil society).
- **People-centric sustainable built environment**: The objective of this Partnership is to generate the necessary technology and socio-economic breakthroughs for an improved built environment supporting the socio-economic transition towards sustainability and the achievement of EU 2050 decarbonisation goals. The partnership goes beyond buildings, taking forward and broadening the activities of the 'Energy-efficient Buildings' PPP under Horizon 2020. The scope of the partnership extends to the whole life-cycle of the built environment (buildings, transport infrastructures, etc.). It will bring together the entire sector, from both the supply side and the demand side, in order to consider aspects such as energy performance, environmental impact, material and resource efficiency, as well as societal innovation towards sustainability and decarbonisation, all this driven by the user-centric approach.. These complex challenges call for a partnership approach which is driven by innovation and pulled by citizen demand for clean, safer, affordable, smarter, decarbonised and sustainable living.
- **Towards zero-emission road transport (2ZERO)**: **Towards zero-emission road transport (2ZERO)**: The Partnership aims to accelerate the transformation of the road transport system to a new fuel and powertrain base. Making an essential contribution to mitigating climate change while improving air quality, it will target further development of

highly efficient battery-electric vehicles, their infrastructure (including interfaces) and innovative use services, leading to innovation at system scale. 2ZERO has a clear objective: Europe remains the world leader in innovation, production and services in the field of zero-emission mobility. It will build on and widen the current European Green Vehicle Initiative (EGVI cPPP) The Partnership approach is essential for building consensus among the diverse road transport stakeholders on research and innovation roadmaps/priorities and for allowing the needed synergies to support innovative solutions across the entire value chain, also acting as a catalyst for supporting commitments from the private side.

- **Mobility and Safety for Automated Road Transport (MOSART)**: This initiative will contribute to significantly improve road safety and traffic efficiency (thus reducing system-wide fuel consumption and emissions) by addressing problems hindering the uptake of automated mobility systems and services on roads in the EU. It includes notably the lack of systemic and interoperable solutions at EU level, and the slow market update of research and innovation results and aims at maintaining EU industry leadership in this field. A Partnership is needed to bring together a broader spectrum of stakeholders to better align research and innovation efforts at European and Member State levels and to coordinate public and private investments.
- **Batteries: Towards a competitive European industrial battery value chain**: This partnership will support the development of a world-class European research and innovation ecosystem on batteries, with a view to build an European industrial leadership in the design and production of batteries for both stationary and mobile applications. It will support technological leadership in the field of current and particularly the development of future battery technologies beyond 2030. A Partnership approach will allow establishing close collaboration of all relevant actors along the complete batteries value chain, entailing clear commitment of partners to provide additional resources and investments. It will establish synergies with other European Partnerships depending on innovative batteries (e.g. 2ZERO, Clean Aviation).
- **Clean Energy Transition**: This Partnership will contribute to the 'Green Deal', put forward by the President of the European Commission, and to the objective of a fully decarbonised energy system by 2050. The complexity and scale of this challenge calls for a Partnership approach enabling the coordination of relevant EU instruments, private sector engagements and funding programmes in and among Member States. The proposed partnership will address the clean energy transition in a cross-thematic context, allowing a just transition for all citizens, regions and Member states and enabling the decarbonisation of all economic sectors - including energy-intensive industry - in a circular economy.
- **Sustainable, Smart and Inclusive Cities and Communities**: This partnership will support European cities in designing and implementing the required transformation for transition to sustainable urbanisation and climate neutrality in line with relevant EU and international policy frameworks such as SDGs, the EU Green Deal, Paris Agreement, Urban Agenda of the EU and the Habitat III New Urban Agenda. It will focus on innovation, in particular in the public sector (e.g capacity building, smart specialisation). It will have an ecosystem approach, addressing also peri-urban areas. It will align EU, national, regional and municipal research and innovation agendas and the rolling out of joint calls and activities to promote EU-wide collaboration, engagement and mobilisation of all relevant resources.
- **Zero-emission waterborne transport**: The partnership will create a foundation for shipping that underpins a climate neutral future, with the demonstration of deployable zero-emission solutions, suitable for all main ship types and services by 2030. It will also contribute to maintaining and further reinforcing Europe's global leadership in green shipping technologies. The partnership is expected to mobilise a critical mass of public and private actors in waterborne transport, which are committed to the urgent development of the necessary knowledge, technology and operational solutions, while ensuring and accelerating their deployment.

Activities within the Cluster "Climate, Energy and Mobility" will also be closely related and collaborate with relevant EIT KICs, in particular the EIT InnoEnergy, EIT Climate KIC and EIT

Urban mobility. In addition, a candidate European Partnership on a Geological Service for Europe would contribute to this cluster by providing expertise and data services in areas of energy storage and carbon capture storage.

7. Missions

Depending on the scope of future specific Missions, activities within the Cluster Climate, Energy and Mobility are expected to be particularly relevant to the Mission(s) identified within the "Climate-Neutral and Smart Cities" and the "Climate Adaptation including Societal Transformation" mission areas, as well as other mission areas.

ANNEX 6 - CLUSTER 6: FOOD, BIOECONOMY, NATURAL RESOURCES, AGRICULTURE AND ENVIRONMENT

1. Global Challenges and their Drivers

Human activities – driven by rapidly growing global population, 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 and is now exceeding "planetary boundaries". Without transformative changes in the current, linear modes of production and consumption, the demand for natural resources is projected to double between 2015 and 2050[131,132].

Natural resources, including soil and biodiversity, are further degraded in terms of quantity and quality because of the impacts of climate change. If current trends continue, global average temperature increase could reach 2°C and considerably more in some regions soon after 2060 and continue to rise afterwards, leading to major adverse impacts on primary production systems[133], natural systems and societies in rural, coastal and urban areas[134,135].

The continuous, accelerating decline in biodiversity is of particular concern since biodiversity provides the fabric of life with a range of ecosystems services, which provide the food we eat, the water we drink, and the environment we live in[136]. 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 governance[137]. Currently, 27% of assessed species in the EU and 66% of habitat types are threatened – pollinators[138] are of specific concern. Worldwide, about 1 million animal and plant species are now threatened with extinction, more than ever before in human history. The situation may become worse under the business as usual scenario[139]. At the same time, transformative changes could bend the curve of biodiversity loss, but they are currently not happening quick, up-scaled or integrated enough[140].

The way we currently use land and soil – vital and finite resources in Europe – is not sustainable. On the one hand, the pressures on land and soils are expected to continue growing because of the competing demands for the production of food, energy and biomaterials or land use changes for urbanisation, industry and infrastructures. In the EU, one-fourth of our productive land is under the threat of erosion. Globally, more than 75 % of Earth's land areas are substantially degraded. If this trend continues, more than 90 % of the Earth's land areas could become degraded by 2050[141]. 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 EU.

Water is a precondition for human, animal and plant life as well as an indispensable resource for the economy. Around the world, communities, farmers, industries, energy suppliers and ecosystems are increasingly competing for their daily water. Access to adequate water has become

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[131] European Commission, Raw Materials Scoreboard 2018

[132] http://www.resourcepanel.org/reports/global-resources-outlook

[133] Primary production systems include agriculture, forestry, aquaculture and fisheries

[134] https://www.ipcc.ch/sr15/

[135] IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (2019), https://www.ipcc.ch/srocc/home/

[136] https://www.ipbes.net/assessment-reports/eca

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

[138] EU Pollinators initiative COM/2018/395 final

[139] https://www.ipbes.net/assessment-reports/eca; https://www.ipbes.net/assessment-reports/eca

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

[141] https://reporterre.net/IMG/pdf/sols-ipbes_re_sume_pour_les_de_cideurs-mars_2018.pdf

a highly contested issue and water resources management had to face continuous changes in values and structural transformations in society and the environment. The overuse and mismanagement of natural resources in the last century has placed a great pressure on freshwater ecosystems[14]. Major emerging challenges are to secure water for all, to achieve a good status for all of Europe's waters, to manage water with social equity, economic efficiency with a circular economy posture and environmental integrity, as well as to implement the EU water policy framework.

Oceans, seas, lakes and rivers are key lungs and farms of our planet; they produce half of the oxygen we breathe and 16 % of the animal protein we eat. Yet, the health and productivity of our oceans, seas, lakes and rivers is severely endangered by climate change, overexploitation, ocean acidification, deoxygenation, excess nutrients, chemical pollutants and plastics. The patterns of biodiversity loss and ecosystem degradation seen across all EU regional seas indicate that many species and habitats are in a poor state[16]. Marine litter is accumulating in European seas, with plastics being the dominant litter in all European regional seas. A major challenge is to tackle marine and freshwater ecosystem degradation and to create a sustainable, circular, and blue economy that is based on sufficient quantities of water as well as on healthy and functioning freshwater and marine ecosystems for the benefit of the current and future generations.

All in all, the global ecological footprint of human activities has increased from requiring less than one Earth in 1961 to more than 1.7 Earths today, and is expected to require two planet Earths around 2030[142]. Already now, we are reaching or even crossing "planetary boundaries" of Earth system in a number of areas related to nutrient flows (notably nitrogen pollution and depletion of phosphorus) and biosphere integrity[143]. Accordingly, concerns over environment-related risks for the economy and society are mounting[144].

These concerns are particularly justified for the EU economy, which is largely dependent on fossil resources and many raw materials sourced from international markets[145]. This when, as a matter of fact, the mass-scale use of fossil resources has significantly contributed to anthropogenic climate change. Industrial operations represent about 20 % of the EU's total GHG emissions, of which about half originates from the use of fossil resources as raw material and from industrial processes[146]. Access to raw materials is a strategic European issue. Sustainable use of raw materials are a key to the ecological transition and digital revolution. A genuine European circular economy could be a way to combat the climate change and biodiversity loss, as well as to reignite the European industrial competitiveness. The use of biomass and waste for the production of renewable products (e.g., chemicals, materials) and nutrients has the potential to strongly contribute to breaking-down the dependence on non-renewable and mineral resources and act as an enabler of the overall bioeconomy.

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 today[147]. More than 70% of the diseases caused by pollution are non-communicable diseases (NCDs)[148].

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

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[142] https://www.footprintnetwork.org/our-work/ecological-footprint/

[143]https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html;

[144] In the last three 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-2019https://www.weforum.org/reports/the-global-risks-report-2019

[145] https://ec.europa.eu/eurostat/data/database https://ec.europa.eu/eurostat/data/database

[146] 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

[147] https://www.thelancet.com/commissions/pollution-and-health https://www.thelancet.com/commissions/pollution-and-health

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

obesity rates in the last several decades[149] and, at present, more than half of the EU's adult population is overweight or obese[150]. The transformation to healthy and sustainable diets requires substantial dietary shift from the consumers and a change in the food production, especially from animal to plant proteins[151,152]. 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. Such a shift provides simultaneous benefits for climate, biodiversity, global food security, human health and a long-term sustainable food system.

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[153,154]. Although the food supply in the EU was never so safe as today, the World Health Organisation estimates that food-borne bacteria, parasites, toxins and allergens cause about 23 million cases of illnesses and 5 000 deaths in Europe every year[155] and the European citizen is not fully confident or trusting the food supply systems[156,157]. Fostering regulatory science to support risk assessment and risk management is necessary to make sure that food stays safe at every stage of the food supply systems.

While addressing all these challenges comes at a price, the costs of inaction and related societal implications would be much higher[158]. If left unaddressed, the effects of climate change combined with the degradation of our natural capital risk undermining public health and many economic sectors, which depend on the health of ecosystems and on the quality of natural resources such as water, soil, and air. 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, agroecology and the food system provide an opportunity to balance environmental, social, and economic goals and set human activities on a path to sustainability[159]. To implement these concepts and address sustainability challenges, new knowledge (including a better access to data), diversity of technological, methodological and social innovations as well as thriving place-based innovation ecosystems are instrumental. In addition, transition to sustainability requires societal engagement 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, costal and urban territories in the Member States, across the EU and globally.

[149] https://www.sciencedirect.com/science/article/pii/S0140673614604608;

[150] http://www.euro.who.int/en/health-topics/noncommunicable-diseases/obesity/data-and-statistics;

[151] https://euagenda.eu/upload/publications/untitled-74063-ea.pdf

[152] https://www.thelancet.com/commissions/EAT

[153] http://www.fao.org/3/a-i6583e.pdf

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

[155] 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=1255;

[156] https://www.sciencedirect.com/science/article/pii/S0924224418305557;

[157] https://ec.europa.eu/info/consultations/public-consultation-transparency-and-sustainability-eu-risk-assessment-food-chain_en

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

[159] 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

2. EU Policy Objectives

The **Green Deal**[160] puts the transition towards more sustainable and socially just ways of producing, consuming and trading, while preserving and restoring our ecosystems, at the heart of EU actions. These guidelines build on a long-term EU ambition to lead the transition to a sustainable, climate-neutral, circular, environment-friendly and inclusive economy in full compliance with the United Nations 2030 Agenda, the Paris Climate Agreement and the Convention on Biological Diversity, reiterated in recent communications, notably "Clean Planet for All"[161] and "Towards a Sustainable Europe by 2030"[162].

Research and innovation under Cluster 6 will support the Green Deal by improving the scientific knowledge on the underlying drivers of sustainability challenges as well as by providing a range of diverse options and solutions to address them. It needs be matched with investment in technologies, digitalisation, new business and governance models as well as social and environmental innovation to overcome lock-ins and set humanity on more sustainable pathways.

Cluster 6 will therefore be instrumental in supporting the design, implementation and evaluation of initiatives of the Green Deal, as part of the Commission 2019-2024 political guidelines, related to, *inter alia*:

- Climate change,
- Biodiversity Strategy for 2030,
- "Farm to Fork Strategy" for sustainable food along the whole value chain,
- Cherishing and protecting rural areas and investing in their future,
- Zero-pollution ambition; cross-cutting strategy to protect citizens' health from environmental degradation and pollution, addressing air and water quality, hazardous chemicals, industrial emissions, nitrogen emissions, pesticides and endocrine disrupters (in cooperation with Cluster 1),
- New Circular Economy Action Plan, especially in resource-intensive and high-impact sectors, such as construction and textiles, feeding into overall Industrial Strategy and addressing the issues of micro-plastics on the way towards plastic-free oceans.
- A comprehensive strategy on Africa and trade agreements with sustainable-development chapter.

The forthcoming Just Transition Fund and the Sustainable Europe Investment Plan, notably under the strategy for green financing, will also benefit from and bring benefits to the results research and innovation activities under Cluster 6.

In addition, a number of EU policies and strategies related to the European Green Deal, some of which now being revised, will benefit from the results of research and innovation in Cluster 6, notably the Common Agricultural Policy, the Common Fisheries Policy, the Maritime Policy, EU Arctic Policy, the EU General Food Law, the EU Bioeconomy Strategy, the Blue Growth Strategy, as well as EU environmental legislation and policies targeting biodiversity, water, soil and air. Synergies will be sought with EU structural and investment funds and with LIFE.

Finally, Cluster 6 in cooperation with other Clusters will also contribute to other priorities reiterated in the Commission 2019-2023 political guidelines, i.e.,: an economy that works for people, a Europe fit for the digital age, protecting our European way of life, a stronger Europe in the world and a new push for European democracy.

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[160] https://ec.europa.eu/commission/sites/beta-political/files/political-guidelines-next-commission_en.pdf

[161] COM(2018) 773 final, A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy;

[162] 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;

3. Targeted Impacts

Investments in research and innovation concerning **food, bio-economy, natural resources, agriculture and environment** (Cluster 6) will advance knowledge, build capacities as well as develop and demonstrate innovative solutions to accelerate the transition to a sustainable and circular management and use of natural resources from land and sea, ensuring ecosystem integrity as well as territorially balanced and sustainable development and human well-being, including water, food and nutrition security, in the EU and globally. This will involve user-driven exploitation of environmental big data sources (in particular from the Group on Earth Observations (GEO), Copernicus and Galileo). Cluster 6 will target and contribute to the following impacts:

- Improved knowledge and innovations build the foundations for **climate neutrality** by reducing GHG emission and enhancing the sink and storage functions in production systems[163] and ecosystems, and foster **adaptation** of ecosystems, water management and production systems as well as of rural, coastal and urban areas to **climate chang**e.

The climate mitigation and adaptation potential of terrestrial ecosystems, including soils, and of ecosystems in seas, oceans and inland waters as well as in primary production, food and bio-based systems will be better understood and seized. In particular, innovative GHG neutral and climate-proof production and 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 with innovative approaches. Actions under this Cluster in cooperation with Clusters 4 and 5 will lead to achieve European climate targets. In the longer term this will enhance economic, environmental and social resilience as well as territorial cohesion.

- **Halt of biodiversity decline and restoration of ecosystems** enabled through improved knowledge and innovative solutions towards reaching the global vision for biodiversity 2050.[164]

Biodiversity and ecosystem services in natural systems and in primary production will be better understood, monitored, valued and managed. As a result, innovative solutions will be designed, up-scaled and implemented, reversing the decline of biodiversity, including of pollinators, and enhancing ecosystem integrity and resilience in land and aquatic environments.

- Better understanding of planetary boundaries facilitates innovative solutions for **sustainable and circular management and use of natural resources** as well a**s prevention and removal of pollution,** guaranteeing healthy soils and clean water and air for all as well as boosting competitiveness, value creation and attractive jobs.

The physical and biological planetary boundaries in relation to the use and management of biodiversity and natural resources on land and sea will be better understood and defined. This will provide the basis for innovative solutions for a minimised and more circular use of resources and the mainstreaming of circular systems, including at local and regional levels. As a result, resource efficiency will be increased, and pollution will be reduced all along value chains, from production to consumption and disposal. The efficient management and sustainable use of biological resources will result also in increased and fairly distributed added-value along the whole value chains and their competitiveness as well as more attractive jobs in rural, coastal, peri-urban and urban areas, with a priority on areas which are more socially disadvantaged. Innovative approaches will enable also sustainable management of water resources to better cope with the impacts of floods and droughts (in cooperation with Cluster 3), and reduce the high economic costs related to water pollution control and removal.

[163] Production systems related to sectors covered by Cluster 6

[164] "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people." CBD decision X/2. (Comment MF: This overarching vision will stay valid also if or the Biodiversity Strategy up to 2030, which targets will however only be adopted in autumn 2020)

- Improved knowledge and innovations enhance **sustainable primary production[165], food and bio-based systems, which are inclusive, safe and healthy and** ensure food and nutrition security for all within planetary boundaries.

Thanks to improved knowledge and innovative solutions, 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. The agricultural sector will use water, other natural resources more efficiently. Safe and cost-competitive use of bio-resources from land and sea will be ensured for all. Sustainable, safe and healthy diets will be available and accessible for all and a major shift to healthy diets from sustainable food production systems "from farm to fork" will be achieved.

- Better understanding of the **behavioural, socio-economic and demographic changes** leads to innovative approaches that **drive sustainability** and **a balanced development of vibrant rural, coastal, peri-urban and urban areas.**

Behaviour, motivation, lifestyle and choices of producers, consumers, industry and retailers, will be better understood including on gender aspects. People, as consumers, as producers, as dwellers, as entrepreneurs and as innovators will have equitable access to knowledge and skills required for making informed choices and being actively engaged in sustainable management of natural resources, from production to consumption and disposal. Healthy, biodiversity-friendly and responsible production and consumption will become the norm. Rural communities will see their quality of life and access to opportunities and services improved and will become drivers of innovations. Mobilising the forces of digital transformation and social innovation will facilitate those changes, help to decouple human well-being from resource overexploitation and environmental impacts, and foster a balanced and interlinked development of rural, coastal, peri-urban and urban areas.

- Environmental observations, strengthened evidence base and tools are delivered and used for the **establishment and monitoring of governance models enabling sustainability.**

Policy design, implementation and monitoring needed for achieving the necessary ecological, economic and social transition will be supported by strong evidence-based knowledge and tools. Knowledge and Innovation systems will be in place and encourage multi-actor, participatory, risk-aware, place-based and community-led innovations. This will accelerate the development and adoption of sustainable practices or solutions, and the removal of harmful practices, in particular in relation to scarce natural resources and in the context of the climate and biodiversity crisis. Solid and reliable information will be derived from Environmental Observations to support better understanding of impacts of global changes and enable sound decision making and adaptation measures 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 Research and Innovation Orientations

The present section describes the most important short to medium-term impacts that are expected from research and innovation orientations under each intervention area. The short and medium-term impacts of research and innovation 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 multi-actor involvement as well as interdisciplinary or even transdisciplinary approaches in the research and innovation orientations.

[165] **Primary production** should be understood throughout the annex 6 as agriculture, fisheries, aquaculture and forestry

4.1 Environmental Observation

This research and innovation 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 intervention area 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, e.g. ESA and EUMETSAT), 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 research and innovation 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) and research infrastructures.

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 intervention area 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 conservation and water availability 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).

This intervention area is related to most of the mission areas and many of the proposed European Partnerships, in particular, but not exclusively to the partnership 'Agriculture of data' (Environmental Observation for a Sustainable EU Agriculture). The scope of the partnership is so ambitious that it requires the engagement of the MS in a pro-active way, in order to identify the end-users and reach a critical mass of resources enabling to cope with the challenge at hand.

4.2 Biodiversity and Natural Capital

This research and innovation 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 research and innovation 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, education, 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 multiple ecosystem types (including in global biodiversity hotspots), and thus facilitate the continued provision of all ecosystem services, including for water quality, which underpin our economy and society.

This includes better understanding and addressing the drivers of biodiversity loss and their interactions - changes in land and sea use overexploitation (through intensive agriculture, water use, forestry and fishing practices), climate change, pollution (air, soil and water) 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 replicable and resilient 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 and cultural values, behavioural and bio-physical factors for biodiversity conservation and restoration, including tipping points and planetary boundaries (links with cluster 5).

Assessing and valuing biodiversity, ecosystem and their services and the multi-benefits of nature-based solutions, along with supporting the development and adoption of natural capital accounting frameworks and metrics, will support their mainstreaming in public and private decision-making. A necessary pre-condition for efficient biodiversity action is investment into long-term integrated monitoring (of species, habitats and cumulative threats) 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. Intra-specific diversity will also be taken into account, as well as the open integration of knowledge and data from multiple origins such as molecular, phylogenetic, socio-historical, sensors, satellites, etc., to support private and public decision-making.

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 -including its cascading effect on migratory insectivorous species[166]- and their impact on citizens' life. EU research and innovation 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).

Biodiversity and nature-based solutions interlink with other research and innovation areas, notably health (infectious diseases, microbiome), bioeconomy, agriculture and food systems, especially in a climate change context. Synergies and trade-offs among these must be investigated. 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, IA7 and Cluster 1).

166 Convention on Migratory species. Insect decline and its threat to migratory insectivorous animal populations.

Innovative nature-based solutions will be developed, tested and scale up to reduce pollution, including diffuse water pollution originated from agricultural and urban sources and revitalise degraded ecosystems and reverse biodiversity decline, notably man-made ones as well as human health, understanding systemic and long-term risks and opportunities.. 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). Innovative models harvesting the positive role biodiversity on human health should be developed together with the health sector.

Assessing how extraction, production, consumption, trade, and behaviour patterns, especially primary production and food systems, affect biodiversity loss and ecosystem services, 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 and transformative governance models, participatory approaches and integrated decision-support tools are expected to enable systemic approaches and a swift implementation of policy mixes 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 how behavioural, socio-economic and demographic change could be 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, research community, business and public in all parts of the science-policy cycle, including through education and citizen science, for facilitating co-creation of actions on natural capital and biodiversity.

Another targeted 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).

Biodiversity and nature-based solutions will play a supporting role in several mission areas and European Partnerships, especially the ones related to climate change adaptation and agroecology. In particular, the proposed partnership "Rescuing biodiversity to safeguard life on Earth" will align and integrate pan-European research and innovation efforts in developing and upscaling solutions to stop biodiversity loss and guide actions to protect, restore and sustainably manage ecosystems and natural capital. It will help mainstreaming of biodiversity and will support policy-makers, notably on improving the evaluation and monitoring of the efficiency of biodiversity-relevant policies, developing the science basis and science-policy interface to guide policy implementation, at global, EU and national levels.

Effective communication and dissemination is critical to raise societal awareness of biodiversity and ecosystems. This requires the development of simple and clear messages from science that can resonate with the public and policy-makers and inspire action

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, providing millions of jobs and securing well-being of people, EU's farmers and foresters are important stewards of the natural environment, and thus have significant potential to shape and maintain rural landscapes, promote healthy ecosystems, mitigate the effects of climate change and halt the loss of biodiversity. Vibrant rural areas are

essential for farmers, foresters and other rural dwellers to keep managing EU's land and resources for the rest of society and to achieve the EU's objectives for territorial cohesion [167]. EU research and innovation activities under this intervention area will advance knowledge, build capacities and develop solutions to use land in more sustainable ways and to move to climate-friendly, resilient and socially inclusive agriculture and forestry systems. This transition will be supported by applying principles of agro- and forest ecology and making better use of ecosystem services. Research and innovation will contribute to providing consumers with healthy and nutritious food and to developing new value chains (including urban farming) in rural and urban areas. It will further contribute to a more balanced development of rural areas, based on implementation of effective, evidence-based policies. Overall, research and innovation activities under this intervention area will be instrumental for the European Green Deal, in particular with regard to the "farm to fork" strategy for sustainable food as well as for climate, circular economy and zero-pollution objectives.

Fostering climate change mitigation, and achieving sustainable management and efficient use of natural resources implies for agriculture and forestry that there is a right balance between productivity, climate and environmental goals. Research and innovation activities will speed up action for sustainable soil and land management, enhancing the various functions of soils such as their capacity to capture carbon, reduce greenhouse gas (GHG) emissions (CO_2, CH_4 and NO_2) and buffer the impacts of climate change. Solutions for climate- and environmentally-friendly practices will be developed to effectively reduce emissions of major greenhouse gases and the environmental footprint of agricultural activities. New technologies and business models will further halt land degradation and enable a "de-fossilisation" of land-based primary production (in cooperation with Cluster 4 and 5, and IA2). Research and innovation will unlock the full potential of LULUCF[168] activities in the mitigation of climate change. Results of funded activities will benefit forest management and the delivery of multiple forest services such as the provision of goods, the protection of soils, water and biodiversity or their contribution to climate change adaptation and mitigation. Contribution of wood products from forests and agroforestry to carbon storage will be enhanced (in cooperation with Cluster 4 and 5).

A range of approaches will be developed to enhance resource use efficiency in agriculture, forestry to find alternatives to scarce resources such as water and soils and to decrease the dependency on critical raw materials (together with IA5 and Clusters 4 and 5). A better understanding of nutrient flows, a more effective integration of legume crops in farming systems and the deployment of mixed production systems (e.g. agroforestry, agro-aqua farms) will allow to optimise resource flows and reduce the use of pesticides and fertilizers on-farms and across landscapes. Decreasing pollution of water, soil and air from primary production will contribute to the zero-pollution ambition of the Green Deal. By better linking rural, peri-urban and urban resource flows it will be possible to gain value from local residues and by-products, unlock the potential of the circular economy, and hence create attractive jobs in rural communities. These impacts will be enabled, *inter alia*, by promoting small-scale, bio-based solutions (in cooperation with IA6) and innovations in farming at the interface between agriculture, aquaculture, forestry and energy (in cooperation with IA4 and Cluster 5).

Agriculture and forestry are severely affected by more variable and extreme weather events or water scarcity. Accordingly, there is an urgent need to foster adaptation of primary production to climate change. Research and innovation impacts will increase the resilience of plants and animals to biotic and abiotic stresses by bringing more diversity into farming and forestry systems and provide farmers and other actors in value chains with better-adapted crop varieties and animal breeds. Attention will be directed also to forest resilience in the context of climate change. Moreover, research and innovation outcomes will provide solutions for rural communities and operators 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).

[167] Treaty on the Functioning of the European Union - Article 174

[168] Land Use, Land-Use Change and Forestry (LULUCF), for more information see: https://ec.europa.eu/clima/policies/forests/lulucf_en:

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 agrobiodiversity, wild 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. Research and innovation impacts will also improve conservation, management and use of plant and animal genetic resources, thereby preserving and enhancing agrobiodiversity. Furthermore, results delivered by research and innovation will allow to better assess the impacts of primary production on biodiversity, and deploy nature-based solutions to enhance biodiversity (in cooperation with IA2).

Health and safety in agriculture and forestry, and of their produce, as well as animal welfare are important societal concerns. Addressing these concerns will require a systemic, multidisciplinary approach. Results of research and innovation under this intervention area are expected to enhance capacities to prevent, monitor and control animal and plant pests and diseases including emerging risks, and to address antimicrobial resistance. This will result in the development of prevention measures as well as safe and environmentally friendly methods for plant protection and weed control that substantially reduce the use of contentious pesticides, and thus also enhance the health and well-being of workers in agriculture and forestry, of consumers and of ecosystems (in cooperation with Cluster 1). With regard to improving animal health and welfare, activities will result in a better understanding of environmental and socio-economic drivers of diseases and promote innovative integrated approaches to animal production. The proposed European Partnership "Animal health: fighting infectious diseases" will tackle transboundary animal diseases, anti-microbial resistance and will allow to advance in the implementation of the One-Health concept (in cooperation in Cluster 1).

Improved knowledge on structure and performance of food and non-food value chains will support their redesign and orientated towards sustainability principles. It will allow to better connect producers, consumers and nature, and to capture the value of environmental, health and socio-economic impacts originating from food and bio-based value chains. Results from research and innovation will contribute to the development and strengthening of value chains of eco-innovative products that respond to new opportunities such as the growing consumer demand for healthier and sustainable diets and at the same time improve the income of producers, and minimize the impact of value chains on climate and environment (together with IA5). Particular attention will be given to promoting diverse and healthy products (fruits and vegetables), EU-grown plant proteins[169] and the organic sector[170]. Research and innovation will stimulate mutually beneficial collaboration between farmers, producer organisations, citizens and other actors. This will support the design of sustainable, competitive, resilient, circular and socially responsible food and non-food value chains with a fair distribution of the value added and better balanced power relations (in cooperation with IA5 and IA6). Activities will support the uptake of urban farming to deliver food alongside social and environmental benefits (in cooperation with IA5). New insights, tools and business models will also contribute to improved communication, certification, authentication, traceability and transparency from farm to fork, thereby reconnecting consumers, producers and nature, enhancing consumer trust, empowering rural communities and better reflecting the true value of products (in cooperation with IA5).

The climate, socio-economic and demographic changes in rural areas jeopardise the cohesion of the EU territory. Results of research and innovation will feed into strategies and policies to close the divide between rural and urban areas and benefit rural dwellers and workers (in line with Cork 2.0 Declaration) and generational renewal in farming and rural communities. Vulnerable groups and gender aspects, including women and migrants will receive special attention (in cooperation with Cluster 2). The development of digital services and skills, co-created with and for rural people, will enhance connectivity and service provision in often remote rural areas (including mountain areas) and support smart, green and inclusive rural communities and businesses (in

[169] 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).

[170] https://ec.europa.eu/info/food-farming-fisheries/farming/organic-farming/future-organics

cooperation with Smart Villages and POSEI, and Cluster 4). This will be done through a better understanding and further development of social networks, social capital and social innovation processes and allow for innovations in rural communities that support the sustainability agenda locally, create and retain value from local and regional assets and improve the well-being of people living in rural areas (in synergy with the LEADER programme).

To support governance models for sustainability, research and innovation will deliver data, knowledge and impact measurements that will allow improving the monitoring and evaluation of EU policies addressing agriculture, forestry, related value chains and rural areas in the period 2021-2027 and beyond. Activities will deliver foresights and tools for multidisciplinary assessment of sustainability and circularity, lock-ins, transition pathways and coherence of EU policies. Moreover, they will help to create observation networks of European forests and harmonise data related to forests.

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 IA1 and Cluster 4). This is in line with the recent declaration of EU Member States on "Smart and sustainable digital future for European agriculture and rural areas"[171].

Agricultural knowledge and innovation systems (AKIS) as well as social innovation will be key drivers to speed up the take-up of results (in synergy with the CAP). This will include promoting place-based innovations, strengthening synergies with other EU Funds in particular smart specialisation strategies, reinforcing the multi-actor approach and establishing a network of living-labs on agro-ecology and leaving space for new approaches such as partnerships and missions.

The proposed European Partnership "Animal health: fighting infectious disease"' will provide a cross sectoral research platform bringing together research funding/performing organisations as well relevant industries, notably the pharmaceutical and diagnostics ones, and related stakeholders. It aims to foster large-scale coordination of basic and applied research activities on priority infectious diseases of livestock and zoonoses and related issues. It will hasten the delivery of improved tools, products and services to better predict, prevent, diagnose and manage diseases more efficiently, thus reducing their impact on livestock production (including animal welfare) and on public health, contributing to the fight against anti-drug resistance. The partnership will build on pre-existing public-public partnerships and will connect to industry. A link will be made with the relevant European partnerships under Cluster 1.

The proposed partnership "Accelerating farming systems transition: agro-ecology living labs and research infrastructures" aims at accelerating the transition of farming systems towards more ecological practices by supporting a network of longer-term experimentation spaces embedded in the national and regional knowledge and innovation ecosystems. This network will promote coordinated approaches and ensure knowledge exchange at EU level by fostering place-based open innovation in co-creative environments such as living labs. Involving national and regional authorities in the partnership will facilitate embedment of the research and innovation activities the EC aims to conduct through this partnership in the local and regional innovation ecosystems, while the need to connect these activities, ensure knowledge exchange and Member States ownership of the process justifies EU's involvement and the proposed partnership approach.

The European Partnership "Agriculture of data" (Environmental Observation for a Sustainable EU Agriculture) will be developed together with IA1 and by pursuing synergies with activities in other intervention areas of Cluster 6 and across clusters. It will aim to support sustainable agriculture, especially by maximising the use of the possibilities offered by the digital / data technologies in the field of Earth observations. In order to achieve lasting impact and European outreach, the partnership will imply the involvement of a large community, including Member State authorities.

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,

[171] https://ec.europa.eu/digital-single-market/en/news/eu-member-states-join-forces-digitalisation-european-agriculture-and-rural-areas

seas and inland waters can deliver food with lower carbon and freshwater footprints than land-based production, while boosting profitability in the sector. Sustainable fisheries and mariculture are set to play an increasing role on food and nutrition security and be part of the forthcoming sustainable food from farm to fork Strategy (in cooperation with IA5).

The health of the ocean and fresh water ecosystems, its conservation and protection are a prerequisite to benefit from their services. By the year 2100, without significant changes, more than half of the world's marine species may stand on the brink of extinction[172]. Activities will underpin EU's leading position to advance restoration of biodiversity and ecosystems and its commitment in halting the decline of marine and freshwater species (in cooperation with IA2).The IPCC report on the Oceans and the Cryosphere (2019) provides solid evidence on ominous developments ahead calling for urgent action.

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. The Arctic and Antarctic are among the most sensitive and fragile regions of the globe to human induced climate change and other stressors. Sustained Polar research and observations are increasingly important and necessary to understand the rapid changes taking place in these Regions and to predict their regional and global impacts. Research is also needed for assessing vulnerabilities and building resilience in polar ecosystems and societies.

Contributing to the above, science, technology and innovation are key to the development of a sustainable ocean economy, along with skills and education, 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.

Marine biodiversity remains largely unexplored, offering a huge potential for seemingly endless discoveries of new species and applications in the fields such as food value chain, pharmaceutical bioactive marine-derived compounds, cosmetics, chemicals, materials, etc. Marine biotechnology offers great potential for the exploration of marine organisms, and their communities, and for the development of new products, processes and services (in cooperation with Cluster 1). Ocean exploration, including the deep sea as the least known frontier of the planet, will also enhance the understanding of ecosystems function and the chemical, physical, biological geological earth's cycles (through also IA1 for ocean observation).

Designing and deploying an integrated approach (looking at the interlinkages of ocean-climate (also in cooperation with Cluster 5), ocean-food (in cooperation with IA5), ocean-land, ocean-society, renewable energy from marine sources (also in Cluster 5), 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 level[173].

In light of recent IPCC projections, there is a need to adapt to extreme sea level events and coastal hazards and not in a distant future. Climate change mitigation and adaptation, especially through nature-based solutions (together with IA2 and Cluster 3), 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 sectors[174] as well as on inland waters and related economic activities and human settlements. The development and demonstration of Greenhouse gas "neutral" and climate-proof production and exploitation

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[172] http://www.unesco.org/new/en/natural-sciences/ioc-oceans/focus-areas/rio-20-ocean/blueprint-for-the-future-we-want/marine-biodiversity/facts-and-figures-on-marine-biodiversity/

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

[174] 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;

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 Clusters 3, 4 and 5).

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 areas[175] (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 inland water, coastal and marine resources will be achieved through innovative solutions (including circular economy business models and social innovations – together with IA7) to mitigate and adapt to climate change impact and reduce stressors and human induced pressures - from overfishing to pollution, on freshwater and marine ecosystems. It includes to enhancing the means to fight illegal, unreported and unregulated fisheries. The shared use of maritime space with other activities, particularly in the coastal zone, and its socio-economic impact will be addressed through the development of optimal maritime spatial planning. It will result in better human, algal and animal health, facilitating the development and market uptake of sustainable circular bio-based processes and blue bioeconomy products (in cooperation with IA6).

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).

Establishment of governance models enabling sustainability will benefit from the results of research and innovation, improving capacities and skills to reap the benefits of digital transformation and socio-economic innovations for more resilient, prosperous, sustainable and dynamic inland water, coastal and maritime economies, also by developing management frameworks aligned to policy objectives and ensuring fit for purpose ocean observations[176] (together with IA1), interconnected with relevant research infrastructures[177], to serve the needs of decision and policy making.

Prevention and removal of pollution (chemical, physical, bacteriological, nutrients) will deliver on the EU ambition of zero pollution and will be supported by and required behavioural and socio-economic changes. Research and innovation will lead to solutions to limit pollution in inland, coastal and marine waters, including from maritime infrastructures and transport, energy infrastructures and tourism. Special attention will be given to identifying approaches to reduce pollution in river catchment areas at the scale needed to ensure all fresh and coastal water reach environmental standards defined in the relevant EU water and marine policies, and the quality of the cleaned waste water entering coastal waters. It embraces the adoption of circular economy products to prevent and mitigate littering and pollution, very importantly plastic pollution (together with IA7)

Cost-effective solutions for mitigation of morphological alterations of water bodies (e.g. barriers, dams, and 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

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

[176] 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.

[177] Such as those identified by the European Strategy Forum for Research Infrastructures (ESFRI) and those established under the European Research Infrastructures Consortium (ERIC) regulation

and new emerging pollutants (such as micro-pollutants, micro-plastics, pharmaceuticals, endocrine disrupters, antimicrobial resistant bacteria) will also help improve the chemical status of freshwater and prevent further pollution, both in inland water bodies and coastal waters (in cooperation with Cluster 1 and IA2,IA7).

An overarching partnership "A climate neutral, sustainable and productive Blue Economy" would cut across several of the above impact areas and it would have a key role in achieving the desired impact on a sustainable Blue Economy, creative value added, blue growth and jobs in Europe through a jointly supported research and innovation programme in the European seas, coastal and inland waters. In order to maximise efforts and achieve efficiency gains the partnership would deliver the highest impact by joining efforts and to align certain research priorities/activities in all seas and oceans around Europe - and beyond - and to pool existing and new funding streams from national public and private sources together with EU funding.

The partnership - covering the Atlantic, Arctic, Baltic, Mediterranean, North Sea and Black Sea – would be based on previous work, notably the sea basin specific Strategic Research and Innovation Agendas (SRIAs); Ministerial Declarations; international commitments and already ongoing work and sea basin initiatives developed and facilitated by the Commission, together with the EU Member States, funders and stakeholders over the last 10 years. The objectives would be to support the resilience of marine ecosystems and a transition to a strong, climate neutral and sustainable Blue Economy by 2050; to ensure food security and safety for citizens; to foster the alignment of existing EU and Member State research and innovation priorities; to pool EU and Member State (private and public partners) resources; to support a Europe wide fit-for-purpose marine observation framework by 2030; to increase international cooperation in science, research and innovation as well as science diplomacy; to address Climate mainstreaming'. The partnership would focus on establishing a coherent SRIA which will be implemented with co-programmed and co-funded actions. Multi-lateral cooperation with international partners will be pursued to achieve the goals mentioned above, notably in the Atlantic, the Mediterranean, the Black Sea, the Baltic Sea and the Arctic. It builds on Member States (e.g. Belém Statement, Galway Statement), and international commitments. It will assist in overcoming the challenges related to oceans, seas and inland waters and shaping up global governance by strengthening international research, data sharing and scientific exchanges. Furthermore, the EU is well-placed to demonstrate leadership in relation to the implementation of the United Nations Decade of Ocean Science for Sustainable Development (2021-2030).

Understanding the human dimensions is fundamental to decision-making across marine policy realms. Research and innovation actions will help raising awareness and education to empower European – as 'Ocean Literate' citizens - to take direct and sustainable action towards healthy seas, oceans and inland water, healthy communities and ultimately - a healthy planet. Social innovation will be supported to as a trigger of environmental, social and economic transformations. Synergies between local citizens' ideas and scientific development can create huge added-value for sustainable coastal and marine development.

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. Food systems are also an important part of the bio-economy in terms of turnover and employment, and because of their common ecosystems. This creates synergies, but limits have to be respected. A food systems' transformation is thus required which shifts towards more sustainable and healthy diets and aims to ensure food and nutrition security for all, thus contributing to the "farm to fork" strategy for sustainable food. The Food 2030 initiative is a useful model to follow with its four priority areas of nutrition and health, climate and sustainability, circularity and resource efficiency and innovative communities. Its goal is to use systemic approach to transition and future-proof our food systems.

This requires a better understanding of the interactions between the different components of current food systems, such as the interactions between food, biodiversity and water systems, to maximise co-benefits and accelerate transition. More specifically, the goal is to arrive at 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 positive social, environmental and economic impacts will play an essential role.

Research and innovation solutions will be developed to build climate smart and environmentally sustainable food systems adaptive to climate change, which conserve natural resources, and implement resource-efficient circular economy principles, while reducing environmental footprint. A range of approaches to enhance diversity, sustainability and food quality, and facilitate production, processing and consumption (e.g. plant-based proteins, algae, seafood with a special focus on low trophic species and insects based proteins) will be investigated (in cooperation with IA3 and IA4). Diversity in food systems (including production, processing, distribution and logistics) will be identified to improve biodiversity, resource efficiency and circularity, prevent and reduce food losses and waste, enhance valorisation of inedible (urban) food waste through the production of bio-based products, rethink packaging, and address the environmental pressures affecting our food systems (in cooperation with IA2, IA3, IA4 and IA6). Placed based food systems innovation will be supported and research and innovation solutions applied to ensure the transformation of urban and peri-urban food systems along with a better understanding of the rural urban divide (in cooperation with IA3). Transformation of EU's food system will require focusing on the potential lying in aquatic production, where e.g. seaweeds, fish and mussel production is highly energy efficient. In addition, the application of microbiome-based knowledge will open new avenues to improve human health with higher quality and safer food products, increase the biodiversity of food resources, tackle waste management, enhance productivity and sustainability, and address climate resilience across food systems (in cooperation with Cluster 1, IA2, IA3 and IA4).

Research and innovation solutions will be developed to ensure safe and nutritious food is available, accessible and affordable for all. Helping citizens to adopt sustainable and healthy diets for good health and well-being will help reduce non-communicable diseases (NCDs), hunger, and malnutrition. Innovative personalized nutrition solutions from smart products, new technologies, business tools and models will reduce the incidence of diet related NCDs. They will arise from a better understanding of the needs and predispositions to develop tailored solutions for different targeted groups taking into account gender related issues, in particular for people in a vulnerable stage of life (in cooperation with Cluster 1). Addressing health and nutritional inequalities is crucial to reduce hunger and malnutrition and to support the transition towards greater sustainability. To ensure that nutritious, sustainable and safe food is available, accessible, and affordable for all, and at any time, will involve innovative solutions and strategies tackling the causes of food and nutrition insecurity, identifying food crises and delivering emergency responses (in cooperation with Cluster 1, Cluster 2, IA3 and IA4). This will occur at different levels (e.g. cities, and regions) and for different communities (developing countries, and vulnerable groups such as the elderly, migrants, and low-income groups).

Innovation in the food chain will be addressed while fostering regulatory science. This will lead to improved risk assessment methodologies and new evidence to support robust food safety regulatory frameworks, including those addressing new and emerging food safety risks. Research and innovation will foster solutions for acceptability, trust, transparency, and innovation uptake by citizens. The development of digital innovation and the improved management and sharing of data will optimize the sustainable use of natural resources along the food system, monitoring its potential impacts on natural resources and contribute to foster food safety and authenticity, crisis management, traceability, transparency, and system resilience, to respond to the trend for more personalized, sustainable and healthy food for consumers' benefits, and to increase the competitiveness and sustainability of the European food industries and related food services sectors. Research and innovation solutions for food products, services and process will improve nutritional, structural and functional food properties, food systems sustainability and resources efficiency, reuse, reduction and recycling of water and packaging, reduction of food losses and waste, and of plastic based food packaging and contact materials.

Advances in systems science, behavioral, socio-economic sciences and decision support tools will help drive policies and food system governance at all levels. Research and innovation solutions to better understand the factors (such as urban planning, obesogenic food environments, cultural and socio economic trends) influencing consumer food choice, lifestyle, motivation and decision-making with a special attention to vulnerable people and gender will facilitate and accelerate the transition towards sustainable and healthy food production and consumption. Safe and healthy diets will

increase well-being, reduce the risk factors of diet-related NCDs, help reach climate targets,[178] and support more environmental friendly production and production systems. European food industries and food services will be engaged for their essential role in facilitating dietary change through the provision of good quality, safe, affordable and convenient food with good nutritional and sensorial qualities.

Citizen's empowerment and involvement in informal and formal governance systems with a gender equality 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, will produce knowledge and innovative solutions and strategies in support of evidence-based policy-making, implementation and monitoring and strengthened 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 that also cover awareness raising, education and skills building. Elements of citizen engagement would be implemented within the partnership and related missions.

An overarching partnership on "Safe and sustainable food systems for people, planet and climate" will provide a platform to co-create the healthy, sustainable and inclusive food systems of tomorrow that accelerate the transition towards a carbon neutral Europe by 2050 and contribute to the new "Farm to Fork vision" and action plan under the European Green Deal. This partnership will focus on developing the needed systemic and cross-sectoral EU research and innovation governance relevant to different geographical scales, to foster collective understanding, align research and innovation programmes and leverage investments, develop capacities and skills to address high impact research and innovation transition pathways such as supporting the food safety system of the future to boost consumer trust, foster food safety and food quality; supporting the shift to sustainable and healthy diets and alternative proteins; cutting food system-related waste, in particular food waste and food packaging; and supporting multi-objective urban and place-based food systems transformation in Europe and beyond. It will mobilise diverse partners (e.g. Member States, public and private sector, research organisations, education establishment, foundations and civil society) and resources within and beyond Horizon Europe to implement the European Commission's (EC) FOOD 2030 research and innovation policy framework to future-proof our food systems by delivering co-benefits on nutrition, climate, circularity and place-based innovation, also with view to addressing both land and sea dimensions. This partnership will build on previous work of the Standing Committee for Agricultural Research (SCAR), three Joint Programming Initiatives (FACCE, HDHL, OCEANS), multiple ERA-NETS and the EIT Food and a number of relevant European Technology Platforms, foundations and NGOs that over the last years have confirmed the need to implement a new, systemic and participatory approach to research and innovation policy that is multi and trans-disciplinary and that prioritises the experiences and expertise of all stakeholders within the food system. The partnership will develop a joined–up and policy coherent Strategic Research, Innovation and Investments plan to be implemented by all partners, that will contain a mix of co-programmed and co-funded actions, depending on the pathways. The partnership will also be aligned with other relevant partnerships working in this area to seek synergies and avoid unnecessary duplication (*"in collaboration with Cluster 1 in particular partnership on "Chemical Risk Assessment"*).

4.6 Bio-based Innovation Systems

Bio-based innovation has a major role to play in the sustainable and just transition to a "green" economy that is climate neutral and 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 resource-efficiency goals of the circular economy – for instance through the development of our capacity to turn organic waste and CO_2 from bio-based

[178] 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

processing 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 (in cooperation with Cluster 1 for the health aspects of bio-based innovation and Cluster 4 for industrial symbiosis and sustainable manufacturing), 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 that contributes to climate and biodiversity goals and sustains ecosystems integrity, and on its conversion into bio-based products and crop nutrients as a substitute of fossil and mineral-based products.

Research and innovation is expected to 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 agroecological approaches and blue biomass can be considered such as multi-cropping strategies, agroforestry, multipurpose biomass, the use of perennials and marginal lands, residues mobilisation and use (in cooperation with Cluster 3 for environmental risk prevention and mitigation) as well as climate-resilient crops (e.g. drought, pathogen resistant) (in cooperation with IA3 for varieties' breeding options, and with IA7 for water use) and sustainable aquatic biomasses with potential for scaling up (IA4). 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 rural settings (in cooperation with IA3). A key approach will be the combination of sustainability and functionality of the developed products. Bio-based products can be suitable for various (longer-term) uses (as harvested wood products also replacing fossil-based materials and products), and new end-of-life requirements (such as recyclability, compostability), should show lower environmental 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 economy operating under safe planetary boundaries. Social innovation will contribute to reducing resource consumption and will result in an increased innovation capacity of all actors. This will also help to decouple human well-being from resource overexploitation and environmental impacts.

Research and innovation is expected to 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, replacing fossil-based materials and products in line with the long-term climate strategy 2050. This also includes reuse, repair, remanufacturing and recycling patterns as well as related governance and financing models. 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 to reduce impacts associated to the production and use of synthetic fertilisers (in cooperation with IA7). As bio-based products and processing can 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 one. This includes the capture and use of CO_2 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. Metrics and data on the value generated per unit of biological resources will be developed.

With a view to addressing the previous research and innovation 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, i.e. European Partnership for a circular bio-based Europe, will be assessed. This will take into account the lessons learned from the partnership on Bio-based Industries under Horizon 2020. Synergies will be created with regional and national public funds and other instruments. The partnership supports sustainability-driven innovation for new local value-creation from waste and biomass, driving sustainable, resource-efficient and climate-neutral solutions towards a healthier planet, replacing non-renewable fossil and mineral resources by biomass and waste for renewable products and soil nutrients.

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. Research and innovation is expected to 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 (e.g. chemistry, construction). 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 IA2).

Maximising the impact of bio-based innovation involves the elaboration and establishment of governance models enabling sustainable and inclusive bioeconomy patterns, including consumption patterns, market measures and financial models (in cooperation with the EIC). This key targeted impact cuts across all key research and innovation priorities identified above. Participatory research and innovation is expected to deliver behavioural and socio-economic change resulting in (i) the revitalisation of local communities through e.g. new (small-scale) business models and innovative market-oriented contractual arrangements in value chains, (ii) effective and inclusive public / civil society engagement, mobilisation and mutual learning, trust building and awareness raising, to avoid 'leaving people behind' (e.g. enhanced transparency in environmental and social sustainability assessment of value chains and their final products and services and communication to stakeholders, labelling etc.); (iii) training and skills development as well as recruitment strategies and education.

Research and innovation is expected to result in a deep understanding of multiple boundaries of the bioeconomy and its bio-based component. 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), involving all actors and including life cycle assessment approaches; (ii) international biomass sustainability criteria and certification schemes, and global sustainability-driven bio-based innovations; and; (iii) hierarchy of use of biological and fossil resources (e.g. trade-offs and synergies with food production or other land use, e.g. recreation). 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 Strategy for Plastics in Circular Economy, the updated EU Bioeconomy Strategy, the reflection paper towards a Sustainable Europe by 2030 and the Clean planet for all strategic vision 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, mobility and built environment) and reap their full benefits to circularity and cut greenhouse emissions and other forms of pollution; (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 monitor and measure the progress and accelerate the transition to the circular economy, and tools that could allow consumers/citizens to make better informed choices (vi) integrate circular approaches in all phases of a product life cycle, from design to re-use, recycling and final disposal.

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 (in cooperation with Cluster 5). 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 and its impact on biodiversity, preventing pollution and achieving sustainable management and circular use of natural resources. A holistic approach will help avoid possible conflicts between different sectors and value chains and safeguard the availability of raw materials for the important societal transitions in the fields of energy and mobility (in cooperation with Cluster 5). 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 (in cooperation with Cluster 4, IA 4.9 Circular Industries).

Robust approaches to promote active engagement of citizens and to bring consumers and producers together, to explore the consumer-related aspects of circular economy and identify instruments that can trigger changes in consumer behaviour (notably, increasing transparency about life-cycle footprints of products and services) 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. Research and innovation 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 and biodiversity loss will require adapting water resources and infrastructure management to increased scarcity and flooding, as a result of more frequent and intense extreme weather events and decreased ecosystem services (in cooperation with Clusters 3 and 5). Improved knowledge about the status of waterbodies and about long-term change in resources are essential for adaptation. Innovative solutions for halting pollution and restoring degraded water bodies contribute to maintaining natural capital (together with IA2). Advanced circular urban water systems and deployment of alternative waters sources, including water reuse, and 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 the insurance sector, will be essential to support EU water and climate adaptation related policies (in cooperation with cluster 5 and IA2, IA3, IA4)).

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 agricultural production. Nutrient emissions cause also impact on air, biodiversity, climate and soil. A comprehensive EU policy to balance nutrient cycles is not yet well developed. Research and innovation is needed to look at how the EU could move to living within the planetary boundaries, with regards to nutrient flows. Research and innovation activities related to the nutrient cycle shall include inter alia 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 (together with Clusters 1, 4, 5 and IA3, IA4, IA6).

The high diversity of challenges we are now facing to address the widespread and cross-sectoral impacts of the risks related to water and to secure water for all, and the relevance of water to several intervention areas of Cluster 6 and other clusters of Horizon Europe (Clusters 1, 3, 4 and 5), require a European and global partnership bringing together a broad spectrum of public and private stakeholders. It also requires the alignment and/or integration of different research and innovation agendas, coordination of funding agencies and commitments to implement a long-term strategy that would deliver major changes and impacts. It also requires the implementation of a wide range of research and innovation activities, including networking, training, demonstration and dissemination of innovative solutions. Finally, it requires more synergies between various EU funding mechanisms and investments funds. This is not possible through regular calls for proposals

and traditional collaborative projects. The proposed Water4All partnership will be goal oriented, providing measurable targets at different levels, such as, decentralised solutions, living labs, increased uptake of innovations and shared research infrastructures and data sets. Beyond scientific progress, it will support policymaking, citizens' engagement and business opportunities.

5. International Cooperation

Global challenges require strong global collective engagement. The EU led international developments towards the Paris Agreement and the 2030 Agenda for Sustainable Development. In this context and also as party to the UNFCCC[179], to the UNCCD[180] and to the UNCBD[181] ("the Rio Conventions") it has taken ambitious commitments under this framework to limit global warming (lastly under the Paris Agreement), to achieve land degradation neutrality and to halt biodiversity loss on land and the seas. In 2015, the EU committed to the 2030 Agenda for Sustainable Development. Through successive Framework Programmes the EU supports and contributes to the work of the IPCC[182] and to the IPBES[183], in terms of providing scientific evidence and science-policy-society interfaces.

Progress towards the EU Green Deal entails emphasizing the EU world leadership and renewed opportunities for research and innovation strategic cooperation and partnerships on the global issues of food and nutrition security, integrity of biodiversity or ocean health. Major efforts will continue in strengthening access to environmental observation data and information through the Global Earth Observation System of Systems (GEOSS), with the leadership and support of the European Commission as a co-chair of the Group on Earth Observations (GEO)[184], in order to underpin environmental policies and global commitments such as the SDGs, Sendai Framework for Disaster Risk Reduction 2015-2030, and the Paris Agreement).

International cooperation will be stepped up through strategic alliances in areas, such as food and nutrition security, animal health, soil, climate change, water management, ecosystem restoration or forest management. This will not only involve bilateral cooperation, but also multilateral cooperation, through existing networks, such as the Belmont Forum, the Bio-economy Forum or the establishment of international research consortia[185] (IRCs). The establishment of one IRC is expected in the area of soil and carbon.

The development of an EU-African Union Research and Innovation Partnership will be continued in areas such as food and nutrition security, sustainable agriculture (FNSSA) and climate resilience. The continuation of the partnership FNSSA in Horizon Europe is a response to the level of hunger in Africa, expanding nutritional imbalances, and the need for agriculture and food production systems to sustainably respond to rising demand and the challenge of urbanisation and migration.

Research and innovation Cooperation with China as part of the Food, Agriculture and Biotechnology (FAB) task force will continue on priority themes of mutual interest.

On the basis of the EU-India Water Partnership, and in line with the EU's strategy on India, research and innovation cooperation with India will be pursued on priority areas of mutual interest including water management and treatment, circular economy and nature based solutions for sustainable cities.

International cooperation with Brazil and the wider CELAC region will be encouraged on nature-based solutions, ecosystem restoration and natural capital in order to support relevant EU policies

[179] UN Framework Convention on Climate Change https://unfccc.int/resource/docs/convkp/conveng.pdf

[180] UN Convention to Combat Desertification https://www.unccd.int/

[181] UN Convention on Biological Diversity https://www.cbd.int/

[182] Intergovernmental Panel on Climate Change https://www.ipcc.ch/

[183] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services https://www.ipbes.net/

[184] GEO Mexico City Declaration; GEO Strategic Plan 2016 - 2025

[185] IRCs are flexible platforms that allow coordination of global efforts in a specific area. The IRC Star-Idaz, supported by Horizon 2020 focuses on animal health.

and partnerships, notably addressing the objectives of the UNFCCC, the CBD, the Sendai Framework, Habitat III and the new Urban Agenda.

Leading international cooperation activities in the field of water will be also promoted with a view of supporting relevant EU policies and partnerships and water and science diplomacy. Also cooperation for all European sea basins will be key to achieve the strategic objectives for seas and oceans, particularly through the All-Atlantic cooperation and the cooperation for the Mediterranean.

The EU will continue to work with international partners to step up science, research and innovation in all European sea basins to underpin international ocean governance, ensure food supply from the seas and oceans, advance polar science and knowledge on climate variability and predictive capabilities for changes such as sea level rise, and complete sea floor mapping, including habitats. This will include the further implementation of the Galway and Belém Statements, respectively signed with the US and Canada, and Brazil and South Africa with a vision of building an all Atlantic Ocean Community and by also implementing the bilateral Administrative Arrangements on Marine Research and Innovation Cooperation with Argentina and the Republic of Cabo Verde.

In the Mediterranean, marine research and innovation cooperation with a significant number of members of the Union for the Mediterranean will continue through the BLUEMED initiative. At the same time, a Strategic Research and Innovation Agenda for the Black Sea will be implemented, as part of the Common Maritime Strategy for the Black Sea.

The EU (both European Commission and several of the EU Member States) are actively cooperating with international partners within the Organisation for Economic Co-operation and Development (OECD), especially in the context of the Committee for Scientific and Technological Policy (CSTP) and its Working Parties. Among the areas of future cooperation are the bio-based economy solutions, circular urban bioeconomy and sustainability assessment methodologies of bio-based products.

6. 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 research and innovation funding agencies can create synergies. The following areas for partnerships with centre of gravity in this Cluster are proposed:

- Towards more sustainable farming: agro-ecology living labs and research infrastructures
- European Partnership on Animals and Health
- Environmental Observations for a sustainable EU agriculture (Agriculture of data)
- Rescuing biodiversity to safeguard life on Earth
- A climate neutral, sustainable and productive Blue Economy
- Safe and Sustainable Food Systems for People, Planet & Climate
- European Partnership for a Circular bio-based Europe: sustainable innovation for new local value from waste and biomass
- Water4All: Water security for the planet

In addition to the support to the abovementioned European Partnerships, the Cluster 6 will collaborate with relevant EIT 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 start-ups, scale-ups 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. A candidate European Partnership on a Geological Service for Europe would contribute to this cluster by providing expertise and data services on sustainable subsurface management.

The Standing Committee on Agricultural Research (SCAR) is an established advisory committee for the coordination of research and innovation addressing large parts of this Cluster and has played a key role in identifying research and innovation orientations in this field for many years. The continued use of the SCAR advisory committee is key to achieving the targeted impacts of Cluster 6.

7. Missions

Depending on the scope of future specific Missions, activities within the Cluster Food, Bioeconomy, Natural Resources, Agriculture and Environment are expected to be particularly relevant to the Mission(s) identified within the "Soil Health and Food", the "Climate Adaptation including Societal Transformation" and the "Healthy Oceans, Seas, Coastal and Inland Waters" mission areas, as well as other mission areas.

ANNEX 7 – MISSION AREAS AND PARTNERSHIP CANDIDATES

1. Mission Areas

1.1 Mission Area for Adaptation to Climate Change, including Societal Transformation

Addressing sectors, policies and systemic, transformative solutions (governance, technological, non-technological, services, behaviour changes, investments) in fields including notably: climate change adaptation and mitigation; climate services; natural resources; systemic and nature-based solutions; environmental advocacy and citizen engagement; sustainable production and consumption; disaster risk reduction and management including public health and critical infrastructures; international development in the field of climate change; science communication; water management; biodiversity; agriculture, finance and insurance.

1.2 Mission Area for Cancer

Addressing sectors, policies and systemic, transformative solutions (governance, technological, non-technological, services, behaviour changes, investments), in fields including notably: cancer prevention, prediction, detection, diagnosis and treatment including clinical expertise in these areas; quality of life and end of life care; public health policy and practice; patient representation including support groups and family counselling, innovation and business development; ethics.

1.3 Mission Area for Healthy Oceans, Seas, Coastal and Inland Waters

Addressing sectors, policies and systemic, transformative solutions (governance, technological, non-technological, services, behaviour changes, investments), in fields including notably: systemic solutions for the prevention, reduction, mitigation and removal of marine pollution including plastics; transition to a circular and blue economy; public awareness raising; users affected by the need to adapt to and mitigate pollution and climate change in the ocean; sustainable use and management of ocean resources; development of new materials including biodegradable plastic substitutes, new feed and food; urban, coastal and maritime spatial planning; ocean governance; ocean economics applied to maritime activities.

1.4 Mission Area for Climate-neutral and Smart Cities

Addressing sectors and policies for systemic, transformative solutions (governance, technological, non-technological, services, behaviour changes, investments), in fields including notably: climate change mitigation and adaptation; air quality; spatial planning (incl. land urban and green spaces) and development; energy efficient buildings (retrofitting); urban infrastructures and networks, including transport and logistics systems, energy, ICT and water; clean energy transformation; urban manufacturing; urban circularity and regeneration; ecosystem services and nature-based solutions; public health and well-being in cities; urban resilience; social impacts of climate change.

1.5 Mission Area for Soil Health and Food

Addressing sectors and policies for systemic, transformative solutions (governance, technological, non-technological, services, behaviour changes, investments), in fields including: soil management in agriculture and forestry for food and nutrition security, and the delivery of non-food products and public goods; soil management beyond agriculture and forestry, e.g. peatland, wetland; restoration and remediation of soils, brownfields, soil sealing; potential of soils and soil management practices for climate mitigation and adaptation; soil functions and ecosystems' services, and the role of practises to improve soil health; sustainable land(scape) management, land use and land use change, spatial planning; ecology, agro-ecology, soil microbiology; systems science / systems approaches, considering financial impacts of soil and land degradation.

2. Candidates for European Partnerships

Preliminary list of candidates for European Partnerships in Pillar II, III and cross-pillar, and short description of what the partnership stands and aims for		Form of implementation	Predecessors	Composition of partners	Relevance for clusters
Health	**1. EU-Africa Global Health Partnership** Increase health security in sub-Saharan Africa and Europe, by accelerating the clinical development of effective, safe, accessible, suitable and affordable health technologies as well as health systems interventions for infectious diseases with a universal health coverage perspective in partnership with Africa and international funders.	Article 185 or Article 187 or Co-programmed or co-funded	EDCTP2 (Art.185)	MS/AC/3rd countries (i.e. sub-Saharan African countries) Foundations/industry on an ad-hoc basis	Cl.1
	2. Innovative Health Initiative A collaborative platform bringing the pharmaceuticals, diagnostics, medical devices, imaging and digital sectors together for precompetitive research and innovation in areas of unmet public health need, to accelerate the development and uptake of people-centred health care innovations.	Article 187 or Co-programmed	IMI2 (Art.187)	Industry, other organisations on an ad hoc basis	Cl.1
	3. European partnership for chemicals risk assessment Bring together the European risk assessment and regulatory agencies to implement a joint research agenda, to ensure their capacity to deal with persistent or emerging challenges. It will promote the uptake of new methods, tools, technologies and information in chemical hazard identification and risk assessment, sustain the development and use of human biomonitoring capacities in Europe.	Co-funded	HBM4EU (Human Bio-monitoring) and a number of other actions	MS/AC, National agencies, role of the corresponding EU agencies tbd	Cl.1, 4, 6
	4. Fostering an ERA for health research The partnerships aims for establishing and implementing a strategic research agenda and joint funding strategy between major European public funders in health research.	Co-funded	Ca. 10 previous and current ERA-NET actions	MS / AC	Cl.1, 6
	5. Health and Care Systems Transformation Improving health and care models in an ageing, data-driven and digital society, shifting to holistic health promotion and person-centred care approaches through health policy and health systems research.	Co-funded	AAL2 (Art.185), JPI 'More Years, Better Lives' and others	MS / AC	Cl.1
	6. Personalised Medicine To align national research strategies, promote excellence, reinforce the competitiveness of European players in Personalised Medicine and enhance the collaboration with non-EU countries.	Co-funded	ERA-PerMed and ICPerMed	MS/AC/3rd countries	Cl.1
	7. Rare Diseases To improve the integration, the effectiveness, the production and the social impact of research on rare diseases through the development, demonstration and promotion of Europe/ world-wide production, sharing and exploitation of research and clinical data, materials, processes, knowledge and know-hows.	Co-funded	EJP Rare diseases	MS/AC /3rd countries, civil society, organisations, EU research infrastructures	Cl.1
	8. One Health AMR The partnership aims to bring together the many aspects of antimicrobial resistance	Co-funded	ERA-NET EXEDRA, JPI	MS/AC	Cl.1, 4, 6

	(AMR) to overcome the fragmentation of the AMR research landscape, and integrate the various different research fields (addressing human and animal health, food safety and environment). It will contribute to the EU One health action plan against AMR.		AMR, One Health EJP		

Digital, Industry and Space	**9. High Performance Computing** The EuroHPC will establish an integrated world-class supercomputing & data infrastructure and support a highly competitive and innovative HPC and Big Data ecosystem.	Article 187 or Co-programmed	EuroHPC (Art 187)	Industry and MS/AC	Cl.4
	10.Key Digital Technologies Maintain the European Electronics Components and Systems industry at the technological forefront and contribute to boosting the EU's competitiveness, including that of its industries by providing essential components and software as well as the related manufacturing infrastructure in Europe and national strategies.	Article 187 or Co-programmed	ECSEL (Article 187), part of Photonics cPPP	Industry and MS/AC (research funders)	Cl.1, 2, 4, 5
	11. Smart Networks and Services Enabling the infrastructure basis in terms of key technologies and deployment for Next-Generation Internet services used by citizens and for "smart" services required by vertical sectors such as transport, energy, manufacturing, health and media.	Article 187 or Co-programmed	cPPP 5G	Industry and academia in the field of connectivity	Cl.1, 4, 5
	12. AI, data and robotics The partnership on AI will help structuring the European AI community, develop a strategic research agenda and federate efforts around a topic that holds great potential to benefit our society and economy	Co-programmed	cPPPs on Big Data and robotics	Industry, academia, end-users, and civil society	Cl. 3, 4
	13. Photonics Europe Photonics is one of the key drivers for tomorrow´s digital markets and the development of the digital European society as a whole. Photons will replace electrons in many of our most important technologies and digital products.	Co-programmed	cPPP Photonics21	Industry	Cl.1, 2, 4, 5, 6
	14. Clean Steel - Low Carbon Steelmaking Provide a EU critical mass to ensure and in particular to upscale breakthrough technology, facilitate joint vision development, agenda setting and synergies of different EU funds, contribute to the evolution to a programming approach in research and innovation.	Co-programmed	Fuel cell and Hydrogen (Article 187) cPPP Spire	Industry	Cl.4, 5
	15. European Metrology Accelerating the global lead in metrology research that Europe currently holds, and creating sustainable metrology networks for highly competitive and emerging metrology areas, while incorporating a wide range of stakeholders.	Article 185 or co-funded	EMPIR (Article 185)	MS/AC (National Metrology Institutes)	Cl.1, 2, 4, 5, 6
	16. Made in Europe Towards a competitive discrete manufacturing industry with a world-leading reduction of the environmental footprint whilst guaranteeing the highest level of well-being for workers, consumers and society.	Co-programmed	cPPPs Factories of the Future, part of Robotics and Photonics	Industry	Cl.1,4 5, 6
	17. Carbon Neutral and Circular Industry Transforming European process industries to make them carbon neutral by 2050, to turn them into circular industries together with material and recycling industries, and to enhance their technological leadership at global level and international competitiveness.	Co-programmed	cPPP SPIRE	Industry CSO/NGOs	Cl.4, 5, 6

	18. Global competitive space systems Perform fast and structured advances on selected innovative critical space systems research and innovation roadmaps such as for example reusability, in orbit demonstration, assembly and manufacturing, so as to acquire global industrial leadership	Co-programmed	n.a.	Industry MS/AC	Cl.4
	19. Geological Service for Europe Further integrate national services to provide key advice and data services to the EU on sustainable subsurface management, integrating geo-resources and environmental conditions across all relevant economic and societal clusters, supported by a world leading subsurface information platform. A coordinated approach to geoscientific research and innovation will help improve pan-European harmonisation, standardisation, knowledge sharing and cutting edge developments in 3D and 4D modelling and geological mapping.	Co-funded	GeoERA ERA-NET	MS/AC	Cl.3, 4, 5, 6
Climate, energy and mobility	**20. Transforming Europe's rail system** Define, design and implement the full spectrum of rail research and innovation activities, from fundamental research to large-scale demos, to trigger a major transformation of the railway system as the backbone of an integrated and sustainable mobility in Europe, maximising socio-economic benefits	Article 187 or Co-programmed	Shift to Rail (Article 187)	Industry, Railwa Operators and Infrastructure Managers	Cl.5
	21. Integrated Air Traffic Management Enhance the performance of the Union's air traffic management system as technological pillar of the Single European Sky (SES) and more broadly of the air transport sector as a whole.	Article 187 or Co-programmed	SESAR (Article 187)	Industry, Eurocontrol	Cl. 4, 5
	22. Clean Aviation Accelerate and amplify the impact of the European aviation research and innovation on Energy Union, Mobility Package, renewed industrial policy strategy, EU GHG and air pollution emissions, including for 2050 horizon and noise regulations, tackling energy and climate-change challenges, industrial competiveness, "first mover advantage" on international markets, and sustainable mobility.	Article 187 or Co-programmed	Clean Sky 2 (Article 187)	Industry	Cl .4, 5
	23. Clean Hydrogen Accelerating the market entry of nearly-zero GHG-emission hydrogen-based technologies across energy, transport & industrial end-users, covering the full value chain for competitive hydrogen and fuel cells technologies, ensuring pole position for Europe to realise the potential of hydrogen technologies at scale.	Article 187 or Co-programmed	Fuel Cell and Hydrogen (Article 187)	Industry	Cl. 4, 5
	24. Built environment and construction Generate the necessary technology and socio-economic breakthroughs for an improved built environment to support the achievement of EU 2050 decarbonisation goals and the transition to clean energy and circular economy, while improving quality of living, health and wellbeing for people, ensuring a high degree of mobility and creating competitive ecosystems for business.	Co-programmed	Energy-efficient Buildings cPPP	Industry	Cl .4, 5
	25. Towards zero-emission road transport (2ZERO) Accelerating the transformation of the road transport system into zero-emission mobility through world-class European research and innovation and industrial system, with a	Co-programmed	European Green vehicle initiative (cPPP)	Industry	Cl. 4, 5

	competitive new generation of light weight, energy efficient and affordable vehicles and support measures to facilitate their rapid deployment				

	26. Mobility and Safety for Automated Road Transport Long-term framework to the strategic planning of research and pre-deployment programmes for connected and automated driving on roads at EU and national levels in a systemic approach (vehicle, interactions, infrastructure, technical and non-technical enablers and societal impact)	Article 187 or Co-programmed	related: 5G, Big Data, ECSEL, S2R, SESAR, batteries, 2ZERO	Industry	Cl. 4, 5
	27. Zero-emission waterborne transport To radically transform inland and maritime waterborne transport, develop knowledge, technologies and demonstrate solutions that will enable zero-emission shipping for all ship types and services. It will contribute to further reinforcing Europe's global leadership in green shipping technologies. This will create a foundation for shipping to underpin a carbon neutral future with the demonstration of deployable zero-emission solutions suitable for all main ship types and services by 2030.	Co-programmed	n.a.	Industry	Cl. 4, 5
	28. European industrial battery value chain Development of a world-class European research and innovation system on batteries, with a view towards European industrial leadership. Develop a coherent strategic programme, in cooperation with industry and research community, substantially contributing to fulfilling the Paris Agreement, and enhance the competitiveness of current and emerging European industries along the battery value chain.	Co-programmed	n.a.	Industry	Cl. 4, 5
	29. Sustainable, Smart and Inclusive Cities and Communities It drives research and innovation on urban transitions and provides scientific evidence for urban actors on sustainable urban development with a cross-sectoral, inter- and transdisciplinary approach, implemented through activities beyond joint calls.	Co-programmed, Co-funded	JPI Urban Europe	MS/AC	Cl .3, 4, 5
	30. Clean Energy Transition Respond to the call for decarbonisation in medium- and long-term in a holistic way, synthesizing all fragmented actions to allow for greater integration of relevant research & innovation areas and provide greater impact.	Co-funded	Around 10 existing ERA-NET Cofund actions	MS/AC (RFOs and RPOs)	Cl .5

Food, Bioeconomy, Natural Resources, Agriculture and Environment	**31. Accelerating farming systems transition: agro-ecology living labs&research infrastructures** Grasping short to long-term agroecological processes at landscape level, accelerating the transition towards sustainable climate and environment-friendly farming practices by boosting place-based innovation in a co-creative environment, fostering adoption of innovation by farmers and other actors.	Co-funded	n.a.	MS/AC (RFOs/regional authorities)	Cl.1, 5, 6
	32. Animal health: Fighting infectious diseases The partnership aims to bring sustainable and innovative solutions to tackle infectious animal diseases, including those transmitted between animals and humans (zoonoses) and to contribute to the fight against anti-microbial resistance, implementing the One Health concept. It will support sustainable animal production, reduce trade barriers, and protect consumers.	Co-programmed, Co-funded	A small number of current ERA-NETs	Either MS/AC or Industry, and regulatory agencies	Cl.1, 6
	33. Environmental Observations for a sustainable EU agriculture The objective of the initiative is to support the delivery of a sustainable CAP by improving agricultural practices and farm profitability and using the possibilities the current digital/data technics in the field. New services and applications will be developed for EU's farming sector enabling more efficient, environmentally friendly and profitable production systems.	Co-funded	EuroGEOSS	MS/AC (RFOs, nat./reg. authorities)	Cl. 4, 6
	34. Rescuing biodiversity to safeguard life on Earth Halting biodiversity loss, maintaining and restoring natural capital is essential for the transition towards sustainability, climate neutrality and for respecting the planetary boundaries. The partnership aims to deploy solutions to stop the ongoing mass extinction of species caused by human activity by upscaling, aligning and integrating European research and innovation efforts and investment, guiding actions to protect, restore and sustainably manage ecosystems and natural capital.	Co-funded	ERA-NET Biodiversity, EKLIPSE, ESMERALDA	MS/AC (RFOs, national/regional authorities)	Cl.1, 2, 5, 6
	35. A climate neutral, sustainable and productive Blue Economy The objective is to sustainably unlock, demonstrate and harvest the full potential of Europe's Oceans and Seas through a well-structured, sustained and simplified joint effort in this borderless domain with the aim to support the transition to a strong, climate neutral and sustainable blue economy by 2050.	Co-programmed or Co-funded	BONUS, MARTERA, JPI Oceans, BlueBio	MS/AC (RFOs, nat./reg. authorities), EU Agencies	Cl.1, 2, 4, 5, 6
	36. Safe and Sustainable Food System for People, Planet & Climate Fixing our food system is central to the transition to a 'Sustainable Europe by 2030', and key to meeting the IPCC climate targets and operating within key planetary boundaries. Deploy FOOD 2030 and deliver the Food Safety System of the future, ensuring consumer trust, safety, quality and traceability.	Co-programmed or Co-funded	FACCE Surplus, ICT Agri2, Core-Organic, ERA GAS, SUSAN, ERA HDL, SusFood2	MS/AC (research funders, nat./reg. authorities), EU Agencies	Cl. 6
	37. Circular bio-based Europe: Sustainable, inclusive and circular bio-based solutions Sustainable and climate-neutral solutions accelerating the transition to a healthy planet, where renewable products and nutrients will be produced from biomass and waste instead of non-renewable fossil and mineral resources. This creates awareness, capacities and	Art.187 or Co-programmed	BBI JU	Industry	Cl. 4, 5, 6

	appropriate structures extending beyond industry partners, mobilising producers of biological resources and end-users.				
	38. Water4All: Water security for the planet Secure all water demands in terms of quality and quantity, protect both economic and natural systems, as well as people from water-related hazards. Support the transition to a healthy planet and to ensure a resilient Energy Union, EU climate neutral policy and respect of planetary boundaries.	Co-programmed or Co-funded	Water JPI	MS/AC (RFOs, nat./reg. authorities)	Cl.1, 2, 4, 5, 6

Partnership candidates: Other Pillars	**39. Innovative SMEs** The initiative aims support to transnational market-oriented research projects initiated and driven by innovative SMEs. Innovative SMEs shall take the lead and exploit commercially the project results, thus improving their competitive position. Research organisations, universities, other SMEs, large companies and others actors of the innovation chain can also participate.	Art.185 or co-funded	Eurostars -2	MS/AC (SMEs)	Pillar III
	40. European Science Cloud (EOSC) The partnership is aimed at facilitating the EOSC implementation activities in its second phase. After 2020 the EOSC will become more stakeholder-driven, with a permanent governance structure in place, and would benefit from a co-programmed financing mechanism.	Co-programmed or co-funded	n.a	MS/AC, Academia	Cross-Pillar
	41. EIT Climate-KIC A network of universities, businesses and research organisations delivering solutions mitigate or adapt to climate change and accelerate the deployment of new solutions to market.	EIT-KIC	n.a	MS/AC, Industry, Academia	Pillar III Cl. 5
	42. EIT InnoEnergy It aims at building a sustainable, long-lasting operational framework among the knowledge triangle actors in the energy sector, with the goal of fostering the generation of new talents, the emergence and deployment of new innovative solutions and the creation and development of companies.	EIT-KIC	n.a	MS/AC, Industry, Academia	Pillar III Cl. 5
	43. EIT Digital EIT Digital's mission is to drive digital innovation and develop entrepreneurial talent in order to enhance both economic growth and quality of life across Europe.	EIT-KIC	n.a	MS/AC, Industry, Academia	Pillar III Cl. 4
	44. EIT Health EIT Health will be delivering solutions to enable European citizens to live longer, healthier lives by promoting innovation.	EIT-KIC	n.a	MS/AC, Industry, Academia	Pillar III Cl.1
	45. EIT Food EIT Food will be delivering solutions to develop a highly skilled food sector and collaborate with consumers for products, services and new technologies delivering a healthier lifestyle for all European citizens.	EIT-KIC	n.a	MS/AC, Industry, Academia	Pillar III Cl. 5
	46. EIT Manufacturing EIT Manufacturing will be delivering solutions to transform today's industrial forms of production towards more knowledge intensive, sustainable, low-emission, trans-sectoral manufacturing and processing technologies, to realise innovative products, processes and services.	EIT-KIC	n.a	MS/AC, Industry, Academia	Pillar III Cl. 4
	47. EIT Raw materials EIT Raw Materials will be delivering solutions to boost competitiveness, growth and attractiveness of the European raw materials sector via radical innovation, new educational approaches and entrepreneurship.	EIT-KIC	n.a	MS/AC, Industry, Academia	Pillar III Cl. 4
	48. EIT Urban Mobility EIT Urban Mobility will be delivering solutions to develop a greener, more inclusive, safer and smarter urban transport system.	EIT-KIC	n.a	MS/AC, Industry, Academia	Pillar III Cl. 5
	49. KIC Cultural and Creative Industries It aims at improving the competitiveness and the innovation capabilities in the cultural and creative industries by fostering the generation of talents, supporting emergence and deployment	EIT-KIC	n.a	MS/AC, Industry, Academia	Pillar III Cl. 2

	of innovative solutions, accelerating innovative companies developing solutions in the domain.				