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ANNEXES 1 to 3

ANNEXES

to the

Proposal for a

DECISION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on establishing the specific programme implementing Horizon Europe – the Framework Programme for Research and Innovation

ANNEX I

PROGRAMME ACTIVITIES

The following will be applied in the implementation of the Programme.

STRATEGIC PLANNING

The implementation of Horizon Europe's programme-level objectives in an integrated manner will be ensured by multiannual Strategic Planning. Such planning will provide the focus on impact for the Programme overall and coherence between its different pillars, as well as synergy with other EU programmes and support to and from other EU policies.

The Strategic Planning will promote strong engagement with citizens and civil society organisations at all stages of research and innovation, the co-creation of knowledge, effective promotion of gender equality, including the integration of the gender dimension in research and innovation content, and will ensure and promote the adherence to the highest ethics and integrity standards.

It will include extensive consultations and exchanges with Member States, the European Parliament as appropriate, and with various stakeholders about priorities, including missions, under the 'Global Challenges and Industrial Competitiveness' pillar, and the suitable types of action to use, in particular European partnerships.

Based on such extensive consultations, the Strategic Planning will identify common objectives and common areas for activities such as partnership areas (the proposed legal basis sets out only the instruments and criteria that will guide their use) and mission areas.

The Strategic Planning will help to develop and realise the implementation of policy for the relevant areas covered, at EU level as well as complementing policy and policy approaches in the Member States. EU policy priorities will be taken into consideration during the Strategic Planning process to increase the contribution of research and innovation to the realisation of policy. It will also take into account foresight activities, studies and other scientific evidence and take account of relevant existing initiatives at EU and national level.

The Strategic Planning will promote synergies between Horizon Europe and other Union Programmes, including the Euratom programme, thus becoming a point of reference for research and innovation in all related programmes across the EU budget and non-funding instruments. This will also promote faster dissemination and uptake of research and innovation results and avoid duplication and overlaps between funding possibilities. It will provide the frame for linking the direct research actions of the Joint Research Centre and other actions supported under the Programme, including the use of results for support to policy.

A Strategic Plan will lay out a multiannual strategy for realising content in the work programme (as set out in Article 11), while retaining sufficient flexibility to respond rapidly

to unexpected opportunities and crises. As Horizon Europe is a programme for 7 years, the economic, societal and policy context in which it will operate may change significantly during its life-time. Horizon Europe needs to be able to swiftly adapt to these changes. There will therefore be the possibility to include support for activities beyond the descriptions set out below, where this is duly justified, to address major developments or unforeseen events, policy needs, or crisis situations, for example in response to serious threats to health arising for example from epidemics.

In the implementation of Horizon Europe, particular attention will be paid to ensuring a balanced and broad approach to research and innovation, which is not only limited to the development of new products processes and services on the basis of scientific and technological knowledge and breakthroughs, but also incorporates the use of existing technologies in novel applications and continuous improvement and non-technological and social innovation. A systemic, cross-disciplinary, cross-sectoral and cross-policy approach to research innovation will ensure that challenges can be tackled while also giving rise to new competitive businesses and industries, fostering competition, stimulating private investments and preserving the level playing field in the internal market.

In the 'Global Challenges and Industrial Competitiveness' and the 'Open Innovation' Pillars, research and innovation will be complemented with activities which operate close to the end-users and the market, such as demonstration, piloting or proof-of-concept, excluding however commercialisation activities going beyond the research and innovation phase. This will also include support to demand-side activities that help accelerate the deployment and diffusion of a broad range of innovations. Emphasis will be put on non-prescriptive calls for proposals.

Under the 'Global Challenges and Industrial Competitiveness' pillar, building on experience in Horizon 2020, the social sciences and the humanities will be fully integrated across all clusters, including specific and dedicated activities. Likewise, activities involving marine and maritime research and innovation will be implemented in a strategic and integrated manner in line with the EU Integrated Maritime Policy, the Common Fisheries Policy Policies and international commitments.

'FET Flagships' supported under Horizon 2020 will continue to be supported under this Programme. As they present substantial analogies with missions, other 'FET flagships', if any, will be supported under this Framework Programme as missions geared towards future and emerging technologies.

Science and Technology Cooperation dialogues with the EU's international partners and policy dialogues with the main world regions will make important contributions to the systematic identification of opportunities for cooperation which, when combined with differentiation by country/region, will support priority setting.

While the European Institute of Innovation and Technology's (EIT) focus on innovation ecosystems makes it naturally fit within the Open Innovation pillar of Horizon Europe, the planning of the EIT Knowledge and Innovation Communities (KICs) will be aligned through the Strategic Planning process with the Global Challenges and Industrial Competitiveness pillar.

DISSEMINATION AND COMMUNICATION

Horizon Europe will provide dedicated support for open access to scientific publications, to knowledge repositories and other data sources. Dissemination and knowledge diffusion actions will be supported, also from cooperation with other EU programmes, including clustering and packaging results and data in languages and formats for target audiences and networks for citizens, industry, public administrations, academia, civil society organisations, and policy makers. For this purpose, Horizon Europe may make use of advanced technologies and intelligence tools.

There will be appropriate support for mechanisms to communicate the programme to potential applicants (e.g. National Contact Points).

The Commission will also implement information and communication activities relating to Horizon Europe, to promote the fact that results were obtained with the support of EU funding. They will also seek to raise public awareness on the importance of research and innovation and the broader impact and relevance of EU funded research and innovation, by means of e.g. publications, media relations, events, knowledge repositories, databases, multi-channel platforms, websites or a targeted use of social media. Horizon Europe will also provide support to the beneficiaries to communicate their work and its impact to society at large.

EXPLOITATION AND MARKET UPTAKE

The Commission will establish comprehensive measures for exploitation of Horizon Europe results and the knowledge produced. This will accelerate exploitation towards market uptake and boost the impact of the Programme.

The Commission will systematically identify and record the results of the research and innovation activities under the Programme and transfer or disseminate these results and knowledge produced in a non-discriminatory fashion to industry and enterprises of all sizes, public administrations, academia, civil society organisations and policy-makers, in order to maximise the European added value of the Programme.

INTERNATIONAL COOPERATION

Greater impact will be obtained through aligning actions with other nations and regions of the world within an international cooperation effort of unprecedented scale. Based on mutual benefit, partners from across the world will be invited to join EU efforts as an integral part of initiatives in support of EU action for sustainability, reinforced research and innovation excellence, and competitiveness.

International joint action will ensure effective tackling of global societal challenges and Sustainable Development Goals, access to the world's best talents, expertise and resources, and enhanced supply and demand of innovative solutions.

WORKING METHODOLOGIES FOR EVALUATION

The use of high quality independent expertise in the evaluation process underpins the engagement of the programme across all stakeholders, communities and interests, and is a prerequisite for maintaining the excellence and relevance of the funded activities.

The Commission or funding body will ensure the impartiality of the process, and avoid conflicts of interest in line with Article 61 of the Financial Regulation.

Exceptionally, when justified by the requirement to appoint the best available experts and/or by the limited size of the pool of qualified experts, independent experts assisting or being members of the evaluation committee may evaluate specific proposals for which they declare a potential interest. In this case, the Commission or funding body shall take all necessary remedial measures to ensure the integrity of the evaluation process. The evaluation process will be managed accordingly, including a stage involving an interaction between diverse experts. The evaluation committee will take into account the particular circumstances when identifying proposals for funding.

PILLAR I

OPEN SCIENCE

The search for breakthroughs in understanding and the acquisition of knowledge; the world class facilities needed to achieve this including physical and knowledge infrastructures for research and innovation as well as the means to openly disseminate and share knowledge; and an adequate supply of excellent researchers; are at the very heart of economic, social and cultural progress in all its forms.

Open and excellent science is inextricably linked to the achievement of world leading innovation. Scientific and technological paradigm shifts have been identified as key drivers for productivity growth, competitiveness, wealth, sustainable development and social progress. Such paradigm shifts have historically tended to originate from the public-sector science base before going on to lay the foundations for whole new industries and sectors.

Public investment in research, especially through universities and public research institutions (PRIs) and research facilities, often undertakes the longer-term, higher-risk research and complements the activities of the private sector. Besides this it creates skills, knowhow and experience, new scientific instruments and methodologies, as well creating the networks which transmit the latest knowledge.

European science and researchers have been and continue to be at the forefront in many areas. But this is not a position we can take for granted. There is ample evidence to show that as the pace of research continues to grow, so the number of countries competing to be the best is increasing as well. The traditional challenge from countries such as the United States is now being joined by economic giants such as China and India, from the newly industrialising parts of the world in particular, and from all countries where governments recognise the manifold and abundant returns which derive from investing in research.

1. EUROPEAN RESEARCH COUNCIL (ERC)

1.1. Rationale

Although the EU remains the largest producer of scientific publications in the world, it is essentially a 'mass producer' of knowledge with, relative to its size, comparatively few centres of excellence that standout at the world level and with large areas of average and poor performance. Compared with the US and now China to some degree, the EU still tends to follow a 'distributed excellence model' in which resources are spread across a larger number of researchers and research institutions Another challenge is that in many EU countries the public sector still does not offer sufficiently attractive conditions for the best researchers. These factors compound Europe's relative unattractiveness in the global competition for scientific talent.

The global research landscape is evolving dramatically and becoming increasingly multipolar as a result of a growing number of emerging countries, in particular China, expanding their scientific production. So whereas the EU and the United States accounted for nearly two-thirds of world expenditure on research and development in 2000, this share had fallen to less than half by 2013.

The ERC supports the best researchers with flexible, long-term funding to pursue ground breaking, high-gain/high-risk research. It operates autonomously led by an independent Scientific Council made up of scientists, engineers and scholars of the highest repute and appropriate expertise and diversity. The ERC is able to draw on a wider pool of talents and ideas than would be possible for any national scheme, reinforcing excellence through the way in which the best researchers and the best ideas compete against each other.

Frontier research funded by the ERC has a substantial direct impact in the form of advances at the frontiers of knowledge, opening the way to new and often unexpected scientific and technological results and new areas for research. In turn, this generates radically new ideas which drive innovation and business inventiveness and tackle societal challenges. The ERC also has a significant structural impact, driving up the quality of the European research system over and above the researchers and actions it funds directly. ERC-funded actions and researchers set an inspirational target for frontier research in Europe, raising its profile and making it more attractive for the best researchers worldwide as a place to work, and work with. The prestige of hosting ERC grant- holders creates competition between Europe's universities and research organisations to offer the most attractive conditions for top researchers and can indirectly help them to assess their relative strengths and weaknesses and bring about reforms.

The gap between the research performance of the US and the EU countries has narrowed over the 10 years since the ERC was established. The ERC funds a relatively small percentage of all European research, but from this achieves a disproportionally high scientific impact. The average citation impact of the research supported by the ERC is comparable to that of the world's top elite research universities. The ERC's research performance is extremely high when compared with the world's largest research funders. The ERC funds a great deal of frontier research in many of the research areas that have received the highest numbers of

citations, including those areas that are rapidly emerging. Although ERC funding is targeted to frontier research it has resulted in a substantial number of patents.

So there is clear evidence that the ERC attracts and funds excellent researchers through its calls and ERC actions are producing a substantial number of the most significant and high impact research findings worldwide in emerging areas leading to breakthroughs and major advances. The work of ERC grantees is also highly interdisciplinary and ERC grantees collaborate internationally and publish their results openly across all fields of research including the social sciences and humanities.

There is also already evidence of the longer term impacts of ERC grants on careers, on training highly skilled postdocs and PhDs, on raising the global visibility and prestige of European research and on national research systems through its strong benchmarking effect. This effect is particularly valuable in the EU's distributed excellence model because ERC funded status can replace and serve as a more accurate indicator of research quality than recognition based on the status of institutions. This allows ambitious individuals, institutions, regions and countries to seize the initiative and scale up the research profiles in which they are particularly strong.

1.2. Areas of intervention

1.2.1. Frontier Science

Research funded by the ERC is expected to lead to advances at the frontier of knowledge, with scientific publications of the highest quality, to research results with high societal and economic potential impact and with the ERC setting a clear and inspirational target for frontier research across the EU, Europe and internationally. Aiming to make the EU a more attractive environment for the world's best scientists, the ERC will target a measurable improvement in the EU's share of the world's top 1 % most highly cited publications, and aim at a substantial increase in the number of excellent researchers from outside Europe which it funds. ERC funding shall be awarded in accordance with the following well-established principles. Scientific excellence shall be the sole criterion on which ERC grants are awarded. The ERC shall operate on a 'bottom-up' basis without predetermined priorities.

Broad Lines

– Long-term funding to support excellent investigators and their research teams to pursue ground-breaking, high-gain/high-risk research;

– Starting researchers with excellent ideas to make the transition to independence while consolidating their own research team or programme;

– New ways of working in the scientific world with the potential to create breakthrough results and facilitate commercial and social innovation potential of funded research;

– Sharing experience and best practices with regional and national research funding agencies to promote the support of excellent researchers;

– Raising the visibility of ERC programmes.

1.3. Implementation

1.3.1. The Scientific Council

The Scientific Council is the guarantor of the quality of the activity from the scientific perspective and has full authority over decisions on the type of research to be funded.

In the context of the implementation of the framework programme and in order to carry out its tasks, as set out in Article 7, the Scientific Council will:

(1) Scientific strategy:

- establish the overall scientific strategy for the ERC, in the light of scientific opportunities and European scientific needs;
- establish the work programme and develop the ERC's mix of support measures in line with its scientific strategy;
- establish the necessary international cooperation initiatives including outreach activities, to increase the visibility of the ERC for the best researchers from the rest of the world, in line with its scientific strategy.

(2) Scientific management, monitoring and quality control:

- ensure a world-class peer review system based on fully transparent, fair and impartial treatment of proposals by establishing positions on implementation and management of calls for proposals, evaluation criteria, peer review processes including the selection of experts, the methods for peer review and proposal evaluation and the necessary implementing rules and guidelines, on the basis of which the proposals to be funded will be determined under the supervision of the Scientific Council;
- experts shall be appointed on the basis of a proposal from the ERC Scientific Council in the case of ERC frontier research actions;
- ensure that ERC grants are implemented according to simple, transparent procedures that maintain the focus on excellence, encourage initiative and combine flexibility with accountability by continuously monitoring the quality of the operations and implementation;
- review and assess the ERC's achievements and the quality and impact of the research funded by the ERC and make recommendations for corrective or future actions;
- establish positions on any other matter affecting the achievements and impact of the ERC's activities and the quality of the research carried out.

(3) Communication and dissemination:

- raise the global profile and visibility of the ERC by conducting communication and outreach activities including scientific conferences to promote the ERC's activities and achievements and the results of the projects funded by the ERC with the scientific community, key stakeholders and the general public;

– where appropriate, consult with the scientific, engineering and scholarly community, regional and national research funding agencies and other stakeholders.

– regularly report to the Commission on its own activities.

The members of the Scientific Council shall be compensated for the tasks they perform by means of an honorarium and, where appropriate, reimbursement of travel and subsistence expenses.

The President of the ERC will reside in Brussels for the duration of the appointment and devote most of his/her working time[1] to ERC business. He/she will be remunerated at a level commensurate with the Commission's top management and will be provided by the Dedicated Implementation Structure with the necessary support to carry out his or her functions.

The Scientific Council shall elect from amongst its members three Vice-Chairs who shall assist the President in its representation and the organisation of its work. They may also hold the title of Vice-President of the ERC.

Support will be provided to the three Vice-Chairs to ensure adequate local administrative assistance at their home institutes.

1.3.2. Dedicated Implementation Structure

The dedicated implementation structure will be responsible for all aspects of administrative implementation and programme execution, as provided for in the ERC work programme. It will, in particular, implement the evaluation procedures, peer review and selection process in accordance with the strategy established by the Scientific Council and will ensure the financial and scientific management of the grants. The dedicated implementation structure will support the Scientific Council in the conduct of all of its tasks as set out above including the development of its scientific strategy, its monitoring of the operations and its review and assessment of the ERC's achievements as well as its outreach and communications activities, provide access to the necessary documents and data in its possession, and keep the Scientific Council informed of its activities.

In order to ensure an effective liaison with the dedicated implementation structure on strategy and operational matters, the leadership of the Scientific Council and the Director of the dedicated implementation structure will hold regular coordination meetings.

The management of the ERC will be carried out by staff recruited for that purpose, including, where necessary, officials from the EU institutions, and will cover only the real administrative needs in order to assure the stability and continuity necessary for an effective administration.

[1] In principle at least 80 %.

1.3.3. Role of the Commission

In order to fulfil its responsibilities as set out in Articles 6, 7 and 8 and in the context of its own responsibilities for budget execution, the Commission will:

- ensure the continuity and renewal of the Scientific Council and provide support for a standing Identification Committee for the identification of future Scientific Council members;
- ensure the continuity of the dedicated implementation structure and the delegation of tasks and responsibilities to it taking into account the views of the Scientific Council;
- ensure that the dedicated implementation structure carries out the full range of its tasks and responsibilities;
- appoint the Director and the members of the management of the dedicated implementation structure taking into account the views of the Scientific Council;
- ensure the timely adoption of the work programme, the positions regarding implementing methodology and the necessary implementing rules including the ERC Rules of Submission and the ERC Model Grant Agreement, taking into account the positions of the Scientific Council;
- regularly inform and consult the Programme Committee on the implementation of the ERC activities;
- as responsible for the overall implementation of the Research Framework Programme, monitor the dedicated implementation structure.

2. MARIE SKŁODOWSKA-CURIE ACTIONS (MSCA)

2.1. Rationale

Europe needs a highly-skilled and resilient human capital base in research and innovation that can easily adapt to and find sustainable solutions for future challenges, such as major demographic changes in Europe. To ensure excellence, researchers need to be mobile, collaborate and diffuse knowledge across countries, sectors and disciplines, with the right combination of knowledge and skills to tackle societal challenges and support innovation.

Europe is a scientific powerhouse with around 1.8 million researchers working in thousands of universities, research centres and world-leading companies. However, it is estimated that the EU will need to train and employ at least one million new researchers by 2027 in order to achieve the targets beings set for increased investment in research and innovation. This need is particularly acute in the non-academic sector. The EU must reinforce its efforts to entice more young women and men to a career in research, to attract researchers from third countries, retain its own researchers and reintegrate European researchers working elsewhere back to Europe. In addition, in order to more widely spread excellence, the conditions under which researchers perform must be further improved throughout the European Research Area (ERA). In this respect, stronger links are needed notably with the European Education Area (EEdA), the European Regional Development Fund (ERDF), and European Social Fund (ESF+).

These challenges can best be addressed at EU level due to their systemic nature and to the cross-country effort needed to solve them.

The Marie Skłodowska-Curie Actions (MSCA) focus on excellent research that is fully bottom-up, open to any field of research and innovation from basic research up to market take-up and innovation services. This includes research fields covered under the Treaty on the Functioning of the European Union and the Treaty establishing the European Atomic Energy Community (Euratom). If specific needs arise and additional funding sources become available, the MSCA may target certain activities in specific challenges (incl. identified missions), types of research and innovation institutions, or geographical locations in order to respond to the evolution of Europe's requirements in terms of skills, research training, career development and knowledge sharing.

The MSCA are the main instrument at EU-level for attracting researchers from third countries to Europe, thus making a major contribution to global cooperation in research and innovation. Evidence shows that the MSCA not only have a positive impact on individuals, organisations, and at system level, but also yield high-impact and breakthrough research results while at the same time contributing significantly to societal as well as strategic challenges. Long-term investment in people pays off, as indicated by the number of Nobel Prize winners who have been either former MSCA fellows or supervisors.

Through global research competition between scientists and between host organisations from both the academic and non-academic sector, and through the creation and sharing of high-

quality knowledge across countries, sectors and disciplines, the MSCA contribute notably to the goals of the 'Jobs, growth and investment' agenda, the EU Global Strategy and to the United Nations Sustainable Development Goals.

The MSCA contribute to making the ERA more effective, competitive and attractive on a global scale. This can be achieved by focusing on a new generation of highly-skilled researchers and providing support for emerging talent from across the EU and beyond; by fostering the diffusion and application of new knowledge and ideas to European policies, the economy and society, *inter alia* through improved science communication and public outreach measures; by facilitating cooperation between research-performing organisations; and by having a pronounced structuring impact on the ERA, advocating an open labour market and setting standards for quality training, attractive employment conditions and open recruitment for all researchers.

2.2. Areas of Intervention

2.2.1. Nurturing Excellence through Mobility of Researchers across Borders, Sectors and Disciplines

The EU must remain a reference for excellent research and thus attractive for the most promising researchers, European and non-European alike, at all stages of their careers. This can be achieved by enabling researchers and research-related staff to move and collaborate between countries, sectors and disciplines and thus benefit from high-quality training and career opportunities. This will facilitate career moves between the academic and non-academic sector as well as stimulate entrepreneurial activity.

Broad Lines

– Mobility experiences within or outside Europe for the best or most promising researchers regardless of nationality to undertake excellent research and develop their skills as well as career in both the academic and non-academic sector.

2.2.2. Fostering new Skills through Excellent Training of Researchers

The EU needs a strong, resilient and creative human resource base, with the right combination of skills to match the future needs of the labour market, to innovate and to convert knowledge and ideas into products and services for economic and social benefit. This can be achieved through training researchers to further develop their core research competences as well as enhance their transferable skills such as a creative and entrepreneurial mindset. This will allow them to face current and future global challenges, and improve their career prospects and innovation potential.

Broad Lines

– Training programmes to equip researchers with a diversity of skills relevant to current and future global challenges.

2.2.3. Strengthening Human Capital and Skills Development across the European Research Area

In order to foster excellence, promote cooperation between research-performing organisations and create a positive structuring effect, high-quality training standards, good working conditions and effective career development of researchers need to be more widely spread across the ERA. This will help modernise or enhance research training programmes and systems as well as increasing institutions' worldwide attractiveness.

Broad Lines

- Training programmes to foster excellence and spread best practices across institutions and research and innovation systems;
- Cooperation, production and diffusion of knowledge within the EU and with third countries.

2.2.4. Improving and Facilitating Synergies

Synergies between research and innovation systems and programmes at EU, regional and national level need to be significantly strengthened. This can be achieved in particular through synergies and complementarities with other parts of Horizon Europe such as the European Institute of Innovation and Technology (EIT) and other EU programmes, notably the ESF+, including via a Seal of Excellence.

Broad Lines

- Training programmes and similar research career development initiatives supported through complementary public or private funding sources at regional, national or EU level.

2.2.5. Promoting Public Outreach

The awareness of the programme’s activities and the public recognition of researchers need to be enhanced across the EU and beyond, to raise the global profile of the MSCA and to develop a better understanding of the impact of researchers’ work on citizens’ daily lives, and to encourage young people to embark on research careers. This can be achieved through better dissemination, exploitation and diffusion of knowledge and practices.

Broad Lines

- Public outreach initiatives to stimulate interest in research careers, especially amongst young people;
- Promotion activities to raise the global profile, visibility and awareness of the MSCA;
- Diffusion and clustering of knowledge through cross-project collaboration and other networking activities such as an alumni service.

3. RESEARCH INFRASTRUCTURES

3.1. Rationale

State of the art research infrastructures provide key services to research and innovation communities, playing an essential role in extending the frontiers of knowledge. Supporting research infrastructures at the EU level helps to mitigate what in many cases is the reality of scattered national research infrastructures and pockets of scientific excellence, as well as tackling the low circulation of knowledge across silos.

The overall aim is to endow Europe with world-class sustainable research infrastructures open and accessible to all researchers in Europe and beyond, which fully exploit their potential for scientific advance and innovation. Key objectives are to reduce the fragmentation of the research and innovation ecosystem, avoiding duplication of effort, and better coordinate the development and use of research infrastructures. It is crucial to support open access to research infrastructures for all European researchers as well as, through the European Open Science Cloud (hereafter 'EOSC'), increased access to digital research resources, specifically tackling the currently sub-optimal embracement of open science and open data practises. Equally, the EU needs to tackle the rapid increase of global competition for talent by attracting third country researchers to work with European world-class research infrastructures. Increasing the competitiveness of European industry is also a major objective, supporting key technologies and services relevant for research infrastructures and their users, thus improving the conditions for supply of innovative solutions.

Past framework programmes have made a significant contribution towards the more efficient and effective use of national infrastructures as well as developed with the European Strategy Forum on Research Infrastructures (ESFRI) a coherent and strategy-led approach to policy making on pan-European research infrastructures. This strategic approach has generated clear advantages, including reducing duplication of effort with more efficient overall use of resources, as well as standardising processes and procedures.

EU supported activity will provide added value through: consolidating and optimised existing research infrastructures alongside efforts to develop new infrastructures; establishing the European Open Science Cloud (EOSC) as an effective scalable and sustainable environment for data-driven research; the interconnection of national and regional research and education networks, enhancing and securing high-capacity network infrastructure for massive amounts of data and access to digital resources across borders and domain boundaries; overcoming barriers preventing the best research teams from accessing the best research infrastructures services in the EU; fostering the innovation potential of research infrastructures, focused on technology development and co-innovation as well as increased use of research infrastructures by industry.

And the international dimension of EU research infrastructures must be reinforced, fostering stronger cooperation with international counterparts and international participation in European research infrastructures for mutual benefit.

Activities will contribute to different Sustainable Development Goals (SDGs) such as: SDG 3 – Good Health and Well-Being for People; SDG 7 – Affordable and Clean Energy; SDG 9 – Industry Innovation and Infrastructure; SDG 13 – Climate Action.

3.2. Areas of intervention

3.2.1. Consolidating the Landscape of European Research Infrastructures

The establishment, operation and long-term sustainability of research infrastructures identified by ESFRI is essential for the EU to ensure a leading position in frontier research, the creation and use of knowledge and the competitiveness of its industries.

The European Open Science Cloud (EOSC) should become an effective and comprehensive delivery channel for research infrastructures services and should provide Europe's research communities with the next generation of data services for harvesting, storing, processing (e.g. analytics, simulation, visualisation services) and sharing big science data. The EOSC should also provide researchers in Europe with access to the majority of data generated and collected by research infrastructures as well as to HPC and exascale resources deployed under the European Data Infrastructure (EDI)[2].

The pan-European research and education network will link together and enable remote access to research infrastructures and research resources, by providing interconnectivity between universities, research institutes and research and innovation communities at EU level as well as international connections to other partner networks worldwide.

Broad Lines

- The life-cycle of pan European research infrastructures through the design of new research infrastructures; their preparatory and implementation phase, their early-phase operation in complementarity with other funding sources, as well as the consolidation and optimisation of the research infrastructure ecosystem by monitoring the ESFRI landmarks and facilitating service agreements, evolutions, mergers or decommissioning of pan-European research infrastructures;
- The European Open Science Cloud, including: scalability and sustainability of the access channel; effective federation of European, national, regional and institutional resources; its technical and policy evolution to cope with new research needs and requirements (e.g. usage of sensitive data sets, privacy by design); data inter-operability and compliance with the FAIR principles; and a wide user base;
- The pan-European research and education network underpinning the EOSC and EDI as well as enabling the delivery of HPC/data services in a cloud based environment capable of coping with extreme large data sets and computational processes.

[2] The European Data Infrastructure will underpin the European Open Science cloud by providing world-class High Performance Computing capability, high speed connectivity and leading-edge data and software services.

3.2.2. Opening, Integrating and Interconnecting Research Infrastructures

The research landscape will be significantly enhanced through ensuring openness to key international, national and regional research infrastructures for all EU researchers and integrating their services when necessary so as to harmonise access conditions, improve and enlarge service provision and encourage common development strategy of high tech components and advanced services through innovation actions.

Broad Lines

- Networks that bring together national and regional funders of research infrastructures for the co-funding of trans-national access of researchers;
- Networks of pan EU, national and regional research infrastructures addressing global challenges for the provision of access to researchers as well as for the harmonisation and improvement of the infrastructures' services;
- Integrated networks of research infrastructures for development and implementation of a common strategy/roadmap for technological development required to improve their services through partnership with industry; as well as high-tech components in areas such as scientific instrumentation; and for fostering the use of research infrastructures by industry, e.g. as experimental test facilities.

3.2.3. Reinforcing European Research Infrastructure policy and International Cooperation

Support is needed so that policy makers, funding bodies or advisory groups such as ESFRI are well-aligned towards developing and implementing a coherent and long-term EU strategy on research infrastructures.

Similarly, support to strategic international cooperation will strengthen of the position of European research infrastructures at international level, ensuring their global networking and interoperability and reach.

Broad Lines

- Survey, monitoring and assessment of research infrastructures at EU level, as well as policy studies, communication and training actions, international cooperation actions for research infrastructures, and specific activities of relevant policy and advisory bodies.

PILLAR II

GLOBAL CHALLENGES AND INDUSTRIAL COMPETITIVENESS

Many of the challenges which confront the EU are also global challenges. The scale and complexity of the problems are vast, and need to be matched by the appropriate money, resources and effort in order to find solutions. These are precisely the areas where the EU must work together; smart, flexible and joined-up for the benefit and well-being of our citizens.

Greater impact can be obtained through aligning actions with other nations and regions of the world within an unprecedented international cooperation along the lines indicated by the Sustainable Development Goals and the Paris climate agreement. Based on mutual benefit, partners from across the world will be invited to join EU efforts as an integral part of research and innovation for sustainability.

Research and innovation are key drivers of sustainable growth and industrial competitiveness, and they will contribute to finding solutions to today's problems, to reverse as quickly as possible, the negative and dangerous trend that currently links economic development, the use of natural resources and social issues, and turn it into new business opportunities.

The EU will benefit as user and producer of technologies and industries showcasing how modern industrialised, sustainable inclusive, open and democratic society and economy can function and develop. The growing economic-environmental-social examples of the sustainable industrial economy of the future will be fostered and boosted, be they for: health and well-being for all; or resilient inclusive and secure societies; or available clean energy and mobility; or a digitised economy and society; or a transdisciplinary and creative industry; or space marine or land-based solutions; or food and nutrition solutions; sustainable use of natural resources climate protection and adaptation, all generating wealth in Europe and offering higher quality jobs. Industrial transformation will be crucial.

Research and innovation under this pillar of Horizon Europe is grouped into integrated clusters of activities. Rather than addressing sectors, the investments aim at systemic changes for our society and economy along a sustainability vector. These will only be achieved if all actors, both private and public, engage in co-designing and co-creating research and innovation; bringing together end-users, scientists, technologists, producers, innovators, businesses, educators, citizens and civil society organisations. Therefore, none of the thematic clusters is intended for only one set of actors.

Clusters will develop and apply digital, key enabling and emerging technologies as part of a common strategy to promote the EU's industrial leadership. Where appropriate this will use EU space-enabled data and services.

There will be support to bring technology from lab to market and to develop applications including pilot lines and demonstrators, measures to stimulate market uptake and to boost private sector commitment. Synergies with other programmes will be maximised.

The clusters will boost the quick introduction of first-of-its-kind innovation in the EU through a broad range of embedded activities, including communication, dissemination and exploitation, standardisation as well as support to non-technological innovation and

innovative delivery mechanisms, helping create innovation friendly societal, regulatory and market conditions such as the innovation deals. Pipelines of innovative solutions originating from research and innovation actions will be established and targeted to public and private investors as well as other relevant EU and national programmes.

1. CLUSTER 'HEALTH'

1.1. Rationale

The EU Pillar of Social Rights asserts that everyone has the right to timely access to affordable, preventive and curative health care of good quality. This underlines the EU's commitment to the UN's Sustainable Development Goals calling for universal health coverage for all at all ages by 2030, leaving no one behind, and ending preventable deaths.

A healthy population is vital for a stable, sustainable and inclusive society, and improvements in health are crucial in reducing poverty, in fostering social progress and prosperity, and in increasing economic growth. According to the OECD a 10% improvement in life expectancy is also associated with a rise in economic growth of 0.3-0.4% a year. Life expectancy in the EU increased by 12 years since its establishment as a result of tremendous improvements achieved in the quality of life, education, health and care of its people. In 2015, overall life expectancy at birth was 80.6 years in the EU compared to 71.4 years globally. In the past years, it increased in the EU on average by 3 months annually.

Health research and innovation research and innovation have played a significant part in this achievement but also in improving productivity and quality in the health and care industry. However, the EU continues to face novel, newly emerging or persisting challenges that are threatening its citizens and public health, the sustainability of its health care and social protection systems, as well as the competitiveness of its health and care industry. Major health challenges in the EU include: the lack of effective health promotion and disease prevention; the rise of non-communicable diseases; the spread of antimicrobial drug resistance and the emergence of infectious epidemics; increased environmental pollution; the persistence of health inequalities among and within countries affecting disproportionally people that are disadvantaged or in vulnerable stages of life; the detection, understanding, control, prevention and mitigation of health risks in a rapidly changing social, urban and natural environment; the increasing costs for European health care systems and the progressive introduction of personalised medicine approaches and digitalisation in health and care; and the increasing pressure on the European health and care industry to remain competitive in and by developing health innovation vis-a-vis new and emerging global players.

These health challenges are complex, interlinked and global in nature and require multidisciplinary, cross-sectorial and transnational collaborations. Research and innovation activities will build close linkages between discovery, clinical, epidemiological, environmental and socio-economic research as well as with regulatory sciences. They will harness the combined skills of academia and industry and foster their collaboration with health services, patients, policy-makers and citizens in order to leverage on public funding and ensure the uptake of results in clinical practice as well as in health care systems. They will foster strategic collaboration at EU and international level in order to pool the expertise, capacities and resources needed to create economies of scale, scope and speed as well as to share the expected benefits and financial risks involved.

The research and innovation activities of this global challenge will develop the knowledge base, build the research and innovation capacity and develop the solutions needed for a more effective promotion of health and the prevention, treatment and cure of diseases. Improving

health outcomes will in turn result in increased life expectancy, healthy active lives and productivity of working age people, and sustainability of health and care systems.

Addressing major health challenges will contribute to the EU's policy goals and strategies, notably to the EU Pillar of Social Rights, the EU Digital Single Market, the EU Directive on cross-border healthcare, and the European One Health Action Plan against antimicrobial resistance (AMR), and to the implementation of the relevant EU regulatory frameworks. It will also support the EU's commitment to the United Nation's 2030 Agenda for Sustainable Development 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).

Activities will contribute directly to the following Sustainable Development Goal (SDGs) in particular: SDG 3 – Good Health and Well-Being for People; SDG13 – Climate Action.

1.2. Areas of Intervention

1.2.1. Health throughout the Life Course

People in vulnerable stages of life (birth, infancy, childhood, adolescence, pregnancy, mature and late adulthood), including people with disabilities or injuries, have specific health needs that require better understanding and tailored solutions. This will allow reducing related health inequalities and improving health outcomes to the benefit of active and healthy ageing throughout the life course, in particular through a healthy start of life reducing the risk of mental and physical diseases later in life.

Broad Lines

- Early development and the aging process throughout the life course;
- Maternal, paternal, infant and child health as well as the role of parents;
- Health needs of adolescents;
- Health consequences of disabilities and injuries;
- Independent and active life for the elderly and/or disabled people;
- Health education and digital health literacy.

1.2.2. Environmental and Social Health Determinants

Improved understanding of health drivers and risk factors determined by the social, economic and physical environment in people's everyday life and at the workplace, including the health impact of digitalisation, pollution, climate change and other environmental issues, will contribute to identify and mitigate health risks and threats; to reducing death and illness from exposure to chemicals and environmental pollution; to supporting environmental-friendly, healthy, resilient and sustainable living and working environments; to promoting healthy lifestyles and consumption behaviour; and to developing an equitable, inclusive and trusted society.

Broad Lines

- Technologies for assessing hazards, exposures and health impact of chemicals, pollutants and other stressors, including climate-related and environmental stressors, and combined effects of several stressors;
- Environmental, occupational, social and behavioural factors impacting physical and mental health and well-being of people and their interaction, with special attention to vulnerable and disadvantaged people;
- Risk assessment, management and communication, supported by improved tools for evidence-based decision-making, including alternatives to animal testing;
- Capacity and infrastructures to collect, share and combine data on all health determinants, including exposure, health and diseases at EU and international level;
- Health promotion and primary prevention interventions.

1.2.3. Non-Communicable and Rare Diseases

Non-communicable diseases (NCDs), including rare diseases, pose a major health and societal challenge and call for more effective approaches in prevention, treatment and cure, including personalised medicine approaches.

Broad Lines

- Diagnostics for earlier and more accurate diagnosis and for patient-adapted treatment;
- Prevention and screening programmes;
- Integrated solutions for self-monitoring, health promotion, disease prevention, and management of chronic conditions and multi-morbidities;
- Treatments or cures, including both pharmacological and nonpharmacological treatments;
- Palliative care;
- Assessment of comparative effectiveness of interventions and solutions;
- Implementation research to scale up health interventions and support their uptake in health policies and systems.

1.2.4. Infectious Diseases

Protecting people against cross-border health threats is a major challenge for public health, calling for effective international cooperation at EU and global level. This will involve prevention, preparedness, early detection, treatment and cure of infectious diseases, and also tackling antimicrobial resistance (AMR) following a 'One Health approach'.

Broad Lines

- Drivers for the emergence or re-emergence of infectious diseases and their spread, including transmission from animals to humans (zoonosis), or from other parts of the environment (water, soil, plants, food) to humans;
- Prediction, early detection and surveillance of infectious diseases, including antimicrobial resistant pathogens, healthcare-associated infections and environmental related factors;
- Vaccines, diagnostics, treatments and cures for infectious diseases, including co-morbidities and co-infections;
- Effective health emergency preparedness, response and recovery measures and strategies, involving communities;
- Barriers to the implementation and uptake of medical interventions in clinical practice as well as in the health system;
- Trans-border aspects of infectious diseases and specific challenges in low- and middle-income countries (LMICs), such as tropical diseases.

1.2.5. Tools, Technologies and Digital Solutions for Health and Care

Health technologies and tools are vital for public health and contributed to a large extent to the important improvements achieved in the quality of life, health and care of people, in the EU. It is thus a key strategic challenge to design, develop, deliver and implement suitable, trustable, safe, and cost-effective tools and technologies for health and care, taking due account of the needs of people with disabilities and the aging society. These include artificial intelligence and other digital technologies, offering significant improvements over existing ones, as well as stimulating a competitive and sustainable health-related industry that creates high-value jobs. The European health-related industry is one of the critical economic sectors in the EU, accounting for 3% of GDP and 1.5 million employees.

Broad Lines

- Tools and technologies for applications across the health spectrum and any relevant medical indication, including functional impairment;
- Integrated tools, technologies and digital solutions for human health, including mobile and telehealth;
- Piloting, large-scale deployment, optimisation, and innovation procurement of health and care technologies and tools in real-life settings including clinical trials and implementation research;
- Innovative processes and services for the development, manufacturing and rapid delivery of tools and technologies for health and care;
- The safety, efficacy and quality of tools and technologies for health and care as well as their ethical legal and social impact;
- Regulatory science for health technologies and tools.

1.2.6. Health Care Systems

Health systems are a key asset of the EU social systems, accounting for 24 million employees in the health and social work sector in 2017. It is a main priority to render health systems accessible, cost-effective, resilient, sustainable and trusted as well as to reduce inequalities, including by unleashing the potential of data-driven and digital innovation for better health and person-centred care building on open European data infrastructures. This will advance the digital transformation of health and care.

Broad Lines

- Reforms in public health systems and policies in Europe and beyond;
- New models and approaches for health and care and their transferability or adaptation from one country/region to another;
- Improving health technology assessment;
- Evolution of health inequality and effective policy response;
- Future health workforce and its needs;
- Improving timely health information and use of health data, including electronic health records, with due attention to security, privacy, interoperability, standards, comparability and integrity;
- Health systems resilience in absorbing the impact of crises and to accommodate disruptive innovation;
- Solutions for citizen and patient empowerment, self-monitoring, and interaction with health and social care professionals, for more integrated care and a user-centred approach;
- Data, information, knowledge and best practice from health systems research at EU-level and globally.

2. CLUSTER 'INCLUSIVE AND SECURE SOCIETY'

2.1. Rationale

The EU stands for a unique way of combining economic growth with social policies, with high levels of social inclusion, shared values embracing democracy, human rights, gender equality and the richness of diversity. This model is constantly evolving and needs to deal with the challenges from amongst other things, globalisation and technological change. Europe also has to respond to the challenges arising from persistent security threats. Terrorist attacks and radicalisation, as well as cyber-attacks and hybrid threats, raise major security concerns and put particular strain on societies.

The EU must promote a model of inclusive and sustainable growth while reaping the benefits of technological advancements, enhancing trust in and promoting innovation of democratic governance, combatting inequalities, unemployment, marginalisation, discrimination and radicalisation, guaranteeing human rights, fostering cultural diversity and European cultural heritage and empowering citizens through social innovation. The management of migration and the integration of migrants will also continue to be priority issues. The role of research and innovation in the social sciences and the humanities in responding to these challenges and achieving the EU's goals is fundamental.

European citizens, state institutions and the economy need to be protected from the continued threats of organised crime, including firearms trafficking, drug trafficking and trafficking in human beings. Strengthening protection and security through better border management is also key. Cybercrime is on the increase and related risks are diversifying as the economy and society digitalise. Europe needs to continue its effots to improve cybersecurity, digital privacy, personal data protection and combat the spread of false and harmful information in order to safeguard democratic and economic stability. Lastly, further efforts are required to limit the effects on lives and livelihoods of extreme weather events which are intensifying due to climate change, such as floods, storms or droughts leading to forest fires, land degradation and other natural disasters, e.g. earthquakes. Disasters, whether natural or man-made, can put at risk important societal functions, such as health, energy supply and government.

The magnitude, complexity and trans-national character of the challenges call multi-layered EU action. Addressing such critical social, political, cultural and economic issues, as well as security challenges, only at national level would carry the danger of inefficient use of resources, fragmented approaches and dissimilar standards of knowledge and capacity.

Security research is part of the wider comprehensive EU response to security threats. It contributes to the capability development process by enabling the future availability of technologies and applications to fill capability gaps identified by policy-makers and practitioners. Already, funding to research through the EU's framework programme has represented around 50% of total public funding for security research in the EU. Full use will be made of available instruments, including the European space programme (Galileo and EGNOS, Copernicus, Space Situational Awareness and Governmental Satellite Communications). Synergies are sought with the activities supported by EU-funded defence research and duplication of funding is avoided. Cross-border collaboration contributes to

developing a European single security market and improving industrial performance, underpinning the EU's autonomy.

Research and Innovation activities in this Global Challenge will be overall aligned with the Commission's priorities on Democratic Change; Jobs, Growth and Investment; Justice and Fundamental Rights; Migration; A Deeper and Fairer European Monetary Union; Digital Single Market. It will respond to the commitment of the Rome Agenda to work towards: "a social Europe" and "a Union which preserves our cultural heritage and promotes cultural diversity". It will also support the European Pillar of Social Rights, and the Global Compact for safe, orderly and regular migration. Security research responds to the commitment of the Rome Agenda to work towards "a safe and secure Europe", contributing to a genuine and effective Security Union. Synergies with the Justice Programme and with the Rights and Values Programme, which support activities in the area of access to justice, victims' rights, gender equality, non-discrimination, data protection and promotion of the European citizenship will be exploited.

Activities will contribute directly to the following Sustainable Development Goals (SDGs) in particular: SDG 1 - No Poverty; SDG 4 - Quality Education; SDG – Decent Work and Economic Growth; SDG 9 – Industry, Innovation and Infrastructure; SDG 10 - Reducing Inequalities; SDG 11- Sustainable Cities and Communities; SDG 16 – Peace, Justice and Strong Institutions.

2.2. Areas of Intervention

2.2.1. Democracy

Trust in democracy and political institutions seems to be receding. Disenchantment with politics is increasingly articulated by anti-establishment and populist parties and a resurgent nativism. This is compounded by socio-economic inequalities, high migration flows and security concerns. Responding to present and future challenges requires new thinking on how democratic institutions at all levels must adapt in a context of greater diversity, global economic competition, rapid technological advancements and digitisation, with citizens' experience of democratic discourses and institutions being crucial.

Broad Lines

- The history, evolution and efficacy of democracies, at different levels and in different forms; digitisation aspects and the effects of social network communication and the role of education and youth policies as cornerstones of democratic citizenship;
- Innovative approaches to support the transparency, responsiveness, accountability effectiveness and legitimacy of democratic governance in full respect of fundamental rights and of the rule of law;
- Strategies to address populism, extremism, radicalisation, terrorism and to include and engage disaffected and marginalised citizens;
- Better understand the role of journalistic standards and user-generated content in a hyper-connected society and develop tools to combat disinformation;

– The role of multi-cultural citizenship and identities in relation to democratic citizenship and political engagement;

– The impact of technological and scientific advancements, including big data, online social networks and artificial intelligence on democracy;

– Deliberative and participatory democracy and active and inclusive citizenship, including the digital dimension;

– The impact of economic and social inequalities on political participation and democracies, demonstrating how reversing inequalities and combatting all forms of discrimination including gender, can sustain democracy.

2.2.2. Cultural Heritage

Cultural heritage is the fabric of our lives, meaningful to communities, groups and societies, giving a sense of belonging. It is the bridge between the past and the future of our societies. It is a driving force of local economies and a powerful source of inspiration for creative and cultural industries. Accessing, conserving, safeguarding and restoring, interpreting and harnessing the full potential of our cultural heritage are crucial challenges now and for future generations. Cultural heritage is the major input and inspiration for the arts, traditional craftsmanship, the cultural, entrepreneurial and creative sectors that are drivers of sustainable economic growth, new job creation and external trade.

Broad Lines

– Heritage studies and sciences, with cutting edge technologies including digital ones;

– Access to and sharing of cultural heritage, with innovative patterns and uses and participatory management models;

– Connect cultural heritage with emerging creative sectors;

– The contribution of cultural heritage to sustainable development through conservation, safeguarding and regeneration of cultural landscapes, with the EU as a laboratory for heritage-based innovation and cultural tourism;

– Conservation, safeguarding, enhancement and restoration of cultural heritage and languages with the use of cutting edge technologies including digital;

– Influence of traditions, behavioural patterns, perceptions and beliefs on values and sense of belonging.

2.2.3. Social and Economic Transformations

European societies are undergoing profound socio-economic transformations, especially as a result of globalisation and technological innovations. At the same time there has been an increase in income inequality in most European countries[3]. Forward-looking policies are needed, with a view to promoting inclusive growth and reversing inequalities, boosting

[3] OECD Understanding The Socio-Economic Divide in Europe, 26 January 2017.

productivity (including advancements in its measurement) and human capital, responding to migration and integration challenges and supporting intergenerational solidarity and social mobility. Education and training systems are needed for a more equitable and prosperous future.

Broad Lines

- Knowledge base for advice on investments and policies especially education and training, for high value added skills, productivity, social mobility, growth, social innovation and job creation. The role of education and training to tackle inequalities;
- Social sustainability beyond GDP only indicators especially new economic and business models and new financial technologies;
- Statistical and other economic tools for a better understanding of growth and innovation in a context of sluggish productivity gains;
- New types of work, the role of work, trends and changes in labour markets and income in contemporary societies, and their impacts on income distribution, non-discrimination including gender equality and social inclusion;
- Tax and benefits systems together with social security and social investment policies with a view to reversing inequalities and addressing the negative impacts of technology, demographics and diversity;
- Human mobility in the global and local contexts for better migration governance, integration of migrants including refugees; respect of international commitments and human rights; greater, improved access to quality education, training, support services, active and inclusive citizenship especially for the vulnerable;
- Education and training systems to foster and make the best use of the EU's digital transformation, also to manage the risks from global interconnectedness and technological innovations, especially emerging online risks, ethical concerns, socio-economic inequalities and radical changes in markets;
- Modernisation of public authorities to meet citizens' expectation regarding service provision, transparency, accessibility, openness, accountability and user centricity.
- Efficiency of justice systems and improved access to justice based on judiciary independence and rule of law principles, with fair, efficient and transparent procedural methods both in civil and criminal matters.

2.2.4. Disaster-Resilient Societies

Disasters arise from multiple sources, whether natural or man-made, including those from terrorist attacks, climate-related and other extreme events (including from sea level rises), from forest fires, heat waves, floods, earthquakes, tsunamis and volcanic events, from water crises, from space weather events, from industrial and transport disasters, from CBRN events, as well as those from resulting cascading risks. 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.

Broad Lines

- Technologies and capabilities for first responders for emergency operations in crisis and disaster situations;
- The capacities of society to better manage and reduce disaster risk, including through nature-based solutions, by enhancing prevention, preparedness and response to existing and new risks
- Interoperability of equipment and procedures to facilitate cross-border operational cooperation and an integrated EU market.

2.2.5. Protection and Security

There is a need to protect citizens from and to respond to security threats from criminal including terrorist activities and hybrid threats; to protect people, public spaces and critical infrastructure, from both physical (including CBRN-E) attacks and cyber-attacks; to fight terrorism and radicalisation, including understanding and tackling terrorist ideas and beliefs; to prevent and fight serious crime, including cybercrime, and organised crime; to support victims; to trace criminal financial flows; to support the use of data for law enforcement and to ensure the protection of personal data in law enforcement activities; to support air, land and sea EU border management, for flows of people and goods. It is essential to maintain flexibility rapidly to address new security challenges that may arise.

Broad Lines

- Innovative approaches and technologies for security practitioners (such as police forces, border and coast guards, customs offices), public health practitioners, operators of infrastructure and those managing open spaces;
- Human and social dimensions of criminality and violent radicalisation, in relation to those engaged or potentially engaged in such behaviour as well as to those affected or potentially affected;
- The mind-set of citizens, public authorities and industry to prevent the creation of new security risks and to reduce existing risks, including those from new technologies such as Artificial Intelligence;
- Combatting disinformation and fake news with implications for security;
- Interoperability of equipment and procedures to facilitate cross-border and inter-agency operational cooperation and develop an integrated EU market.
- Ensuring the protection of personal data in law enforcement activities, in particular in view of rapid technological developments.

2.2.6. Cybersecurity

Malicious cyber activities not only threaten our economies but also the very functioning of our democracies, our freedoms and our values. Cyber threats are often criminal, motivated by profit, but they can also be political and strategic. Our future security and prosperity depend

on improving our ability to protect the EU against cyber threats. The digital transformation requires improving cybersecurity substantially, to ensure the protection of the huge number of IoT devices expected to be connected to the internet, including those controlling power grids, cars and transport networks, hospitals, finances, public institutions, factories, homes. Europe must build resilience to cyber-attacks and create effective cyber deterrence.

Broad Lines

- Technologies across the digital value chain (from secure components to cryptography and self-healing software and networks);
- Technologies to address current cybersecurity threats, anticipating future needs, and sustaining a competitive industry;
- A European cybersecurity competence network and competence centre.

3. CLUSTER 'DIGITAL AND INDUSTRY'

3.1. Rationale

To ensure industrial competitiveness and the capacity to address the global challenges ahead, the EU must reinforce and maintain its technological and industrial capacities in the key areas that underpin the transformation of our economy and society.

EU industry provides one out of five jobs and two thirds of private sector R&D investments and generates 80% of EU exports. A new wave of innovation, involving a merging of physical and digital technologies, will trigger huge opportunities for EU industry and improve the quality of life for EU citizens.

Digitisation is a major driver. As it continues at a rapid pace across all sectors, investment in priority areas ranging from artificial intelligence to next generation internet, high performance computing, photonics and nano-electronics, becomes essential for the strength of our economy and the sustainability of our society. Investing, producing and using ICT provides a major boost to EU economic growth, amounting to an increase of 30% between 2001 and 2011 alone.

Key enabling technologies[4] underpin the blending of the digital and the physical worlds, central to this new global wave of innovation. Investing in the development, demonstration and deployment of key enabling technologies, and ensuring a secure, sustainable and affordable supply of raw and advanced materials, will secure EU strategic autonomy and help EU industry to significantly reduce its carbon and environmental footprints.

Specific future and emerging technologies may also be pursued as appropriate.

Space is of strategic importance; around 10% of the EU's GDP depends on the use of space services. The EU has a world-class space sector, with a strong satellite manufacturing industry and a dynamic downstream services sector. Space provides important tools for communication, navigation, and surveillance and opens up many business opportunities especially in combination with digital technologies and other sources of data. The EU must make the most of these opportunities by fully exploiting the potential of its space programmes Copernicus, EGNOS and Galileo, and by protecting space and ground infrastructures against threats from space.

The EU has the unique chance of being a global leader and increase its share of world markets, by showcasing how digital transformation, leadership in key enabling and space technologies, the transition to a low-carbon, circular economy and competitiveness can reinforce each other through scientific and technological excellence.

To make the digitised, circular, low-carbon and low-emission economy a reality, action is needed at EU level because of the complexity of value chains, the systemic and multi-disciplinary nature of the technologies and their high development costs, and the cross-sectoral nature of the problems to be addressed. The EU must ensure that all industrial

[4] The Key Enabling Technologies of the future include advanced materials and nanotechnology, photonics and micro- and nano-electronics, life science technologies, advanced manufacturing and processing, artificial intelligence and digital security and connectivity

players, and society at large, can benefit from advanced and clean technologies and digitisation. Developing technologies alone will not suffice. Industrially-oriented infrastructures, including pilot lines, will help set up EU businesses and in particular SMEs deploy these technologies and improve their innovation performance.

A strong engagement of industry is essential in setting priorities and developing research and innovation agendas, increasing the leverage of public funding, and ensuring the uptake of results. Societal understanding and acceptance are key ingredients for success, as well as a new agenda for industry-relevant skills and standardisation.

Bringing together activities on digital, key enabling and space technologies, as well as a sustainable supply of raw materials, will allow for a more systemic approach, and a faster and more profound digital and industrial transformation. It will ensure that research and innovation in these areas feed into, and contribute to the implementation of, the EU's policies for industry, digitisation, environment, energy and climate, circular economy, raw and advanced materials and space.

Complementarity will be ensured with activities under the Digital Europe Programme, to respect the delineation between both Programmes and avoid any overlaps.

Activities will contribute directly to the following Sustainable Development Goals (SDGs) in particular: SDG 8 - Decent Work and Economic Growth; SDG 9 - Industry, Innovation and Infrastructure; SDG 12 - Responsible Consumption and Production; SDG-13 Climate Action.

3.2. Areas of Intervention

3.2.1. Manufacturing Technologies

Manufacturing is a key driver of employment and prosperity in the EU, producing over three quarters of the EU's global exports and providing over a 100 million direct and indirect jobs. The key challenge for EU manufacturing is to remain competitive at a global level with smarter and more customised products of high added value, produced at much lower energy costs. Creative and cultural inputs will be vital to help generate added value.

Broad Lines

- Breakthrough manufacturing technologies such as additive manufacturing, industrial robotics, human integrated manufacturing systems, also promoted via an EU network of industrially-oriented infrastructures;
- Breakthrough innovations using different enabling technologies (e.g. converging technologies, artificial intelligence, data analytics, industrial robotics, bio-manufacturing, advanced batteries technologies) across the value chain;
- Skills and workspaces fully adapted to the new technologies, in line with European social values;
- Flexible, high-precision, zero-defect and zero-waste cognitive plants and smart manufacturing systems meeting customer needs;
- Breakthrough innovations in techniques for exploring construction sites, for full automation for on-site assembly and prefabricated components.

3.2.2. Key Digital Technologies

Maintaining and autonomously developing strong design and production capacities in essential digital technologies such as micro- and nano-electronics, photonics, software and systems, and their integration as well as advanced materials for these applications will be essential for a competitive EU.

Broad Lines

- Nano-electronics design and processing concepts responding to the specific requirements of digital transformation and global challenges, in terms of functionality, energy consumption and integration;
- Sensing technologies and their co-integration with computational units as the enabler of the Internet of Things, including innovative solutions on flexible and conformable materials for human-friendly interacting objects;
- Technologies as complements or alternatives to nano-electronics, such as neuromorphic computing powering artificial intelligence applications, or integrated quantum computing;
- Computing architectures and low-power processors for a wide range of applications including edge computing, digitisation of industry, big data and cloud, smart energy and connected and automated driving;
- Computing hardware designs delivering strong guarantees of trusted execution, with built-in privacy and security protection measures for input/output data as well as processing instructions;
- Photonics technologies enabling applications with breakthrough advances in functionality and performance;
- System engineering technologies to support fully autonomous systems for trustworthy applications interacting with the physical world, including in industrial and safety critical domains;
- Software technologies enhancing software quality, security and reliability with improved service life, increasing development productivity, and introducing built-in artificial intelligence and resilience in software;
- Emerging technologies expanding digital technologies and bridging the gap from proofs of concept in research to industrial feasibility for relevant markets.

3.2.3. Advanced Materials

The EU is a global leader in advanced materials and associated processes, which make up 20% of its industry base and form the root of nearly all value chains through the transformation of raw materials. To remain competitive and meet citizens' needs for sustainable, safe and advanced materials, the EU must improve the recyclability of materials, reduce the carbon and environmental footprint, and drive cross-sectoral industrial innovation by supporting new applications in all industry sectors.

Broad Lines

– Materials (including plastic, bio-, nano-, two-dimensional, smart and multi-materials) designed with new properties and functionalisation and meeting regulatory requirements (while not leading to increased environmental pressures during their production, use or end-of-life);

– Integrated materials processes and production following a customer-oriented and ethical approach, including pre-normative activities and life-cycle assessment, sourcing and management of raw materials, durability, reusability and recyclability, safety, risk assessment and management;

– Materials enablers like characterisation (e.g. for quality assurance), modelling, piloting and upscaling;

– An EU innovation ecosystem of technology infrastructures[5], identified and prioritised in agreement with Member States, which provide services to accelerate technological transformation and uptake by EU industry, notably by SMEs; this will cover all key technologies necessary to enable innovations in the field of materials;

– Analysis of future and emerging trends in advanced materials and other key enabling technologies;

– Solutions based on design, architecture and general creativity, with a strong user orientation, for adding value to industrial sectors and the creative industries.

3.2.4. Artificial Intelligence and Robotics

Making any object and device intelligent is one of the megatrends. Researchers and innovators developing Artificial Intelligence (AI) and offering applications in Robotics and other areas will be key drivers of future economic and productivity growth. Many sectors including health, manufacturing, construction, and farming will use and further develop this key enabling technology, in other parts of the Framework Programme. Developments must ensure the safety of AI-based applications, assess the risks and mitigate its potential for malicious use and unintended discrimination such as gender or racial bias. It must also be ensured that AI is developed within a framework which respects the EU's values and the Charter of Fundamental Rights of the European Union.

Broad Lines

– Enabling AI technologies such as explainable AI, unsupervised machine learning and data efficiency and advanced human-machine interactions;

– Safe, smart and efficient robotics and complex embodied systems;

– User-driven AI technologies for AI-based solutions;

[5] These are public or private facilities that provide resources and services primarily for the European industry to test and validate key enabling technologies and products. Such infrastructures may be single sited, virtual or distributed, and must be registered in a Member State or a third country associated to the Programme.

– Developing and networking the research competences of AI competence centres across Europe;

– Technologies for open AI platforms including software algorithms, data repositories, robotics and autonomous systems platforms.

3.2.5. Next Generation Internet

The Internet has become a key enabler of the digital transformation of all sectors of our economy and society. The EU needs to take the lead in driving the next generation Internet towards a human-centric ecosystem in line with our social and ethical values. Investing in technologies and software for the Next Generation Internet will improve EU industrial competitiveness in the global economy. Optimising EU wide take up will require large-scale cooperation across stakeholders.

Broad Lines

– Technologies and systems for trusted and energy-efficient smart network and service infrastructures (connectivity beyond 5G, software defined infrastructures, Internet of things, cloud infrastructures, cognitive clouds), enabling real-time capabilities, virtualisation and decentralised management (ultrafast and flexible radio, edge computing, blockchains, shared contexts and knowledge);

– Next Generation Internet applications and services for consumers, industry and society building on trust, interoperability, better user control of data, transparent language access, new multi modal interaction concepts, inclusive and highly personalised access to objects, information and content, including immersive and trustworthy media, social media and social networking;

– Software-based middleware, including distributed ledger technologies, working in highly distributed environments, facilitating data mapping and data transfer across hybrid infrastructures with inherent data protection, embedding artificial intelligence, data analytics, security and control in Internet applications and services predicated on the free flow of data and knowledge.

3.2.6. Advanced Computing and Big Data

High Performance Computing and Big Data have become indispensable in the new global data economy, where to out-compute is to out-compete. High Performance Computing and Big Data analytics are critical to support policy making, scientific leadership, innovation and industrial competitiveness, and to maintain national sovereignty.

Broad Lines

– High Performance Computing (HPC): next generation of key exascale and post-exascale technologies and systems (e.g. low-power microprocessors, software, system integration); algorithms, codes and applications, and analytic tools and test-beds; industrial pilot test-beds and services; supporting research and innovation for a world-class HPC infrastructure, including the first hybrid HPC / Quantum computing infrastructure in the EU;

– Big Data: Extreme-performance data analytics; "Privacy by design" in the analysis of personal and confidential Big Data; technologies for full-scale data platforms for re-use of industrial, personal and open data; data management, interoperability and linking tools; data applications for global challenges;

– Reduced carbon footprint of ICT processes, covering hardware, software, sensors, networks, storage and data centres, and including standardised assessments.

3.2.7. Circular Industries

Europe is at the forefront of the global transition towards a circular economy. Europe's industry should become a circular industry: the value of resources, materials and products should be maintained much longer compared to today, even opening up new value chains.

Primary raw materials will continue to play an important role in the circular economy and attention must be paid to their sustainable production. In addition, entirely new materials, products and processes should be designed for circularity. Building a circular industry will have several advantages for Europe: It will lead to a secure, sustainable and affordable supply of raw materials, which will in turn protect the industry against scarcity of resources and price volatility. It will also create new business opportunities and innovative, more efficient ways of producing.

The objective is to develop affordable breakthrough innovations and deploy a combination of advanced technologies and processes so as to extract maximum value from all resources.

Broad Lines

– Industrial symbiosis with resource flows between plants across sectors and urban communities; processes and materials, to transport, transform, re-use and store resources, combining the valorisation of by-products, waste and CO2;

– Valorisation and life-cycle assessment of materials and product streams with use of new alternative feedstocks, resource control, material tracking and sorting;

– Products for enhanced life-cycle performance, durability, upgradeability and ease of repair, dismantling and recycling;

– Recycling industry, maximising potential and safety of secondary materials and minimising pollution, quality downgrading, and quantity dropouts after treatment;

– Elimination of substances of concern in the production and end-of-life phases; safe substitutes, and safe and cost-efficient production technologies;

– Sustainable supply or substitution of raw materials, including critical raw materials, covering the whole value chain.

3.2.8. Low-Carbon and Clean Industries

Industrial sectors, including energy-intensive industries, contribute millions of jobs and their competitiveness is key for the prosperity of our societies. However, they account for 20% of

the global greenhouse gas emissions and have a high environmental impact (particularly in terms of air, water and soil pollutants).

Breakthrough technologies to achieve significant reductions in greenhouse gases and pollutants, often combined with the technologies for circular industry above, will lead to strong industrial value chains, revolutionise manufacturing capacities and improve the global competitiveness of industry; and at the same time make key contributions to our targets for climate action and environmental quality.

Broad Lines

- Process technologies, including heating and cooling, digital tools and large-scale demonstrations for process performance and efficiency; substantial reductions or avoidance of industrial emissions of greenhouse gases and pollutants, including particulate matter;
- Industrial CO2 valorisation;
- Electrification and use of unconventional energy sources within industrial plants, and energy and resource exchanges between industrial plants (for instance via industrial symbiosis);
- Industrial products that require low or zero carbon emissions production processes through the life cycle.

3.2.9. Space

EU space systems and services reduce costs and improve efficiency, offer solutions to societal challenges, increase societal resilience and foster a competitive and sustainable economy. EU support has been instrumental in helping to realise these benefits and impacts. EU space programmes must evolve to remain at the forefront.

The EU will support synergies between space and key enabling technologies (big data, advanced manufacturing, robotics and artificial intelligence); foster a thriving and entrepreneurial and competitive space sector; and help secure non-dependence in accessing and using space in a safe and secure manner. Activities will be roadmap-based, taking account of the ESA harmonisation process and relevant Member States initiatives, and will be implemented with ESA, as appropriate.

Broad Lines

- European Global Navigation Satellite Systems (Galileo and EGNOS): innovative applications, global uptake including international partners, solutions improving robustness, authentication, integrity of services, development of fundamental elements such as chipsets, receivers and antennas, sustainability of supply chains, new technologies (e.g. quantum technologies, optical links, reprogrammable payloads), towards sustained exploitation of services for impact on societal challenges. Next generation systems development for new challenges such as security or autonomous driving;
- Copernicus: innovative applications, global uptake and international partners, robustness and evolution of services, sustainability of supply chains, sensors, systems and mission concepts (e.g. High Altitude Platforms, drones, light

satellites); calibration and validation; sustained exploitation of services and impact on societal challenges; Earth observation data techniques, big data, computing resources and algorithmic tools. Next generation systems development for new challenges such as climate change, and security;

– Space Situational Awareness: robust EU capacity to monitor and forecast state of the space environment e.g. space weather, space debris and near Earth objects, and new service concepts, such as space traffic management, applications and services to secure critical infrastructure in space and on Earth;

– Secure Satellite Communications for EU governmental actors: solutions for the widest possible range of governmental users and associated user equipment in architectural, technological and system solutions for space infrastructure, supporting the EU's autonomy;

– End-to-end satellite Communications for citizens and businesses: cost-effective, advanced satellite communications to connect assets and people in underserved areas, as part of 5G-enabled ubiquitous connectivity and development of the Internet of Things (IoT), and contributing to the Next Generation Internet (NGI) infrastructure. Enhanced ground segment and user equipment, standardisation and interoperability to ensure EU industrial leadership;

– Non-dependence and sustainability of the supply chain: increased technology readiness levels in satellites and launchers; associated space and ground segments, and production and testing facilities. To secure EU technological leadership and autonomy, improved supply chain sustainability, reduced dependence on non-EU critical space technologies and improved knowledge of how space technologies can offer solutions to other industrial sectors;

– Space ecosystem: in-orbit validation and demonstration services, including rideshare services for light satellites; space demonstrators in areas such as hybrid, smart or reconfigurable satellites, in-orbit manufacturing and assembly, launcher reusability, in-orbit servicing and micro-launchers; breakthrough innovations, and technology transfer, in areas such as recycling, green space, artificial intelligence, robotics, digitisation, cost-efficiency, miniaturisation;

– Space science: exploitation of scientific data delivered by scientific and exploration missions, combined with the development of innovative instruments in an international environment; contribution to precursor scientific missions for the evolution of the Space Programme.

4. CLUSTER 'CLIMATE, ENERGY AND MOBILITY'

4.1. Rationale

The intersection of research and innovation on climate, energy and mobility will address in a highly integrated and effective way, one of the most important global challenges for the sustainability and future of our environment and way of life.

To meet the objectives of the Paris Agreement the EU will need to transition to low-carbon, resource-efficient and resilient economies and societies. This will be based on profound changes in technology and services, to the ways in which businesses and consumers behave, as well as involving new forms of governance. Limiting the increase of global average temperature to well below 2°C, and pursuing efforts to limit the temperature increase to 1.5°C, requires rapid progress in decarbonising the energy system and substantially reducing greenhouse-gas (GHG) emissions from the transport sector[6]. It will also need new impetus to accelerate the pace of developing next-generation breakthroughs as well as demonstrating and deploying innovative technologies and solutions, using also the opportunities provided by digital and space technologies. This will be pursued through an integrated approach encompassing decarbonisation, resource efficiency, reduction of air pollution, access to raw materials and circular economy.

Progress in these sectors - but also across the spectrum of EU industry including agriculture, buildings, industrial processes and product use, and waste management - will require continued efforts to better understand the mechanisms of climate change and the associated impacts across the economy and society, exploiting synergies with national activities, other EU types of actions and international cooperation.

Over the past decade, considerable advances have been made in climate science, in particular in observations and data assimilation and climate modelling. However, the complexity of the climate-system and the need to support implementation of the Paris Agreement, the Sustainable Development Goals and EU policies necessitate a reinforced effort to fill the remaining knowledge gaps.

The EU has established a comprehensive policy framework in the Energy Union strategy, with binding targets, legislative acts and research and innovation activities aiming to lead in developing and deploying efficient energy production systems based on renewables.

Transport ensures the mobility of people and goods necessary for an integrated European single market, territorial cohesion and an open and inclusive society. At the same time, transport has significant negative effects on human health, congestion, land, air quality and noise, as well as safety resulting in numerous premature deaths and increased socio-economic costs. Therefore, sustainable mobility and transport networks need to become clean, safe, smart, secure, silent, reliable and affordable, offering a seamless integrated door-to-door service.

[6] Substantial decarbonisation of other sectors is addressed in other areas of the Horizon Europe Global Challenges and Industrial Competitiveness pillar.

The issues faced by the transport and energy sectors go however beyond the need for emission reduction. There are several challenges to be tackled, including the increasing penetration of digital and space-based technologies, changes in user behaviour and mobility patterns, new market entrants and disruptive business models, globalisation, increasing international competition and an older, more urban and increasingly diverse, population.

Both sectors are major drivers of Europe's economic competitiveness and growth. The EU has upwards of 1.6 million people working in the field of renewables and energy efficiency. Transportation and the storage sectors employ more than 11 million in the EU, accounting for around 5% of GDP and 20% of exports. The EU is a world leader in vehicle, aircraft and vessel design and manufacturing, while patenting of innovative clean energy technologies places the EU in second place worldwide.

Finding new ways to accelerate the deployment of clean technologies and solutions for the decarbonisation of the European economy requires also increased demand for innovation. This can be stimulated through the empowerment of citizens as well as socio-economic and public sector innovation and will lead to approaches broader than technology-driven innovation. Socio-economic research covering inter alia user needs and patterns, foresight activities, environmental, economic, social and behavioural aspects, business cases and models and pre-normative research for standard setting, will also facilitate actions fostering regulatory, financing and social innovation, skills, as well as engagement and empowerment of market players and consumers.

Activities under this Cluster contribute in particular to the goals of the Energy Union, as well as to those of the Digital Single Market, the Jobs, Growth and Investment agenda, the strengthening of the EU as a global actor, the new EU Industrial Policy Strategy, the Circular Economy, the Raw Materials Initiative, the Security Union and the Urban Agenda, as well as the Common Agricultural Policy of the EU as well as EU legal provisions to reduce noise and air pollution.

Activities will contribute directly to the following Sustainable Development Goals (SDGs) in particular: SDG 7 - Affordable and Clean Energy; SDG 9 - Industry, Innovation and Infrastructure; SDG 11 - Sustainable Cities and Communities; SDG 13 - Climate Action.

4.2. Areas of Intervention

4.2.1. Climate Science and Solutions

Effective implementation of the Paris Agreement has to be based on science, requiring continuously updating of our knowledge on the climate-earth system, as well as the mitigation and adaptations options available, allowing for a systemic and comprehensive picture of challenges and opportunities for the EU's economy. On this basis, science-based solutions for a cost-effective transition to a low-carbon, climate-resilient and resource-efficient society will be developed.

Broad Lines

– Knowledge base on the functioning and future evolution of the earth-climate system, as well as associated impacts, risks, and opportunities;

– Decarbonisation pathways, mitigation actions and policies covering all sectors of the economy, compatible with the Paris Agreement and the United Nations Sustainable Development Goals;

– Climate projections and techniques for predictability and climate services for businesses, public authorities and citizens;

– Adaptation pathways and policies for vulnerable ecosystems, critical economic sectors and infrastructure in the EU (local/regional/national), including improved risk assessment tools.

4.2.2. Energy Supply

The EU aims to be world leader in affordable, secure and sustainable energy technologies improving its competitiveness in global value chains and its position in growth markets. Diverse climatic, geographical, environmental and socio-economic conditions in the EU as well as the need to ensure energy security and access to raw materials, dictate a broad portfolio of energy solutions, including of non-technical nature. As regards renewable energy technologies, costs need to decrease further, performance must improve, integration into the energy system must be improved and breakthrough technologies need to be developed. As regards fossil fuels, decarbonising their usage will be essential to meet the climate objectives.

Broad Lines

– Renewable energy technologies and solutions for power generation, heating and cooling, sustainable transport fuels and intermediate carriers, at various scales and development stages, adapted to geographic conditions and markets, both within the EU and worldwide;

– Disruptive renewable energy technologies for new applications and breakthrough solutions;

– Technologies and solutions to reduce greenhouse gas emissions from fossil fuel-based power generation via CO2 capture, utilisation and storage (CCUS).

4.2.3. Energy Systems and Grids

The expected growth of variable electricity production and shift towards more electric heating, cooling and transport dictates the need for new approaches to manage energy grids. Next to decarbonisation, the goal is to ensure energy affordability, security and stability of supply, achieved through investments in innovative network infrastructure technologies and innovative system management. Energy storage in different forms will play a key role in providing services to the grid, also improving and reinforcing network capacities. Exploiting synergies between different networks (e.g. electricity grids, heating and cooling networks, gas networks, transport recharging and refuelling infrastructure, hydrogen, and telecom networks) and actors (e.g. industrial sites, data centres, self-producers) will be crucial for enabling the smart, integrated operation of the relevant infrastructures.

Broad Lines

- Technologies and tools for electricity networks to integrate renewables and new loads such as electro-mobility and heat pumps;
- Pan-European energy network approaches to management;
- Integrated approaches to match renewable energy production and consumption at local level including on islands, based on new services and community initiatives;
- Network flexibility and synergies between the different energy sources, networks, infrastructures and actors;

4.2.4. Buildings and Industrial Facilities in Energy Transition

Buildings and industry installations play an increasingly active role in their interaction with the energy system. Therefore, they are crucial elements in the transition to renewable energy.

Buildings are an important factor for quality of life of citizens. Integrating different technologies, appliances and systems and linking various energy uses, buildings as well as their inhabitants and users represent a very high potential for energy generation, storage and efficiency improvements.

Industries, and especially those that are energy-intensive, could further improve energy efficiency, and favour the integration of renewable energy sources.

Broad Lines

- Electricity and heat between an industrial plant and an energy system operator;
- Tools and infrastructure for process control of production plants to optimise energy flows in interaction with the energy system;
- Relevant processes, design and materials;
- Smart buildings and large mobility hubs (ports, airports, logistic centres) as active elements of wider energy networks and of innovative mobility solutions;
- Buildings life-cycle design, construction, operation and dismantling, taking into account circularity and environmental performance, for energy and resource efficiency, climate resilience, and recycling;
- New business models, approaches and services for renovation financing, enhancement of construction skills, engagement of buildings occupants and other market actors;
- Energy performance of buildings monitoring and optimisation;
- Tools and smart appliances for energy efficiency gains in buildings;
- Renovation processes of existing buildings towards 'Nearly Zero Energy Buildings';

4.2.5. Communities and Cities

It is estimated that by 2050, more than 80% of the EU's population will live in urban areas, consuming the lion's share of available resources, including energy, and being areas particularly vulnerable to the adverse meteorological change impacts worsen by climate change and natural disasters already now and increasingly in the future. A key challenge is to significantly increase the overall energy and resource efficiency as well as climate-resilience of Europe's cities in a holistic fashion, targeting the building stock, energy systems, mobility, climate change, as well as water, soil, air quality, waste and noise. Synergies with ERDF-funded urban policy and actions should be investigated and exploited.

Broad Lines

- City/district energy/mobility systems towards the EU-wide deployment of low-carbon, Positive Energy Districts and zero-emission mobility and logistics by 2050, boosting the global competitiveness of integrated EU solutions;
- Urban planning, infrastructures and systems including mutual interfaces and interoperability, nature-based solutions and the use of digital technologies and space based services and data, taking into account the effects of projected climate change and integrate climate resilience;
- Quality of life for the citizens, safe mobility, urban social innovation, cities' circular and regenerative capacity, reduced environmental footprint and pollution;
- Global cities research agenda.

4.2.6. Industrial Competitiveness in Transport

The shift towards clean technologies, connectivity and automation will depend on the timely design and manufacture of aircraft, vehicles and vessels integrating different technologies and accelerating their introduction. Increasing comfort, efficiency, affordability, while minimising lifecycle impact on the environment, human health and on energy use remain objectives of paramount importance. Innovative, highly capable transport infrastructure is essential for the proper functioning of all transport modes in view of increased mobility demand and rapidly changing technology regimes. An integrated approach to infrastructure and vehicle/vessel/aircraft development deserves particular attention also in order to minimise energy and environmental impact.

Broad Lines

- Merging of physical and digital vehicle/vessel/aircraft design, manufacturing, operations, standardisation, certification and regulations and integration (including integration between digital design and digital manufacturing);
- Vehicle/vessel/aircraft concepts and designs, including their spare parts, using improved materials and structures, efficiency, energy storage and recovery, safety and security features with less environment and health impact.
- On-board technologies and sub-systems, including automated functions, for all modes of transport taking account of relevant infrastructure interface needs and exploring; technological synergies between modes; safety/accidence avoidance

systems and enhancing cybersecurity; developing the human-machine interface;

– New materials, techniques and methods of construction, operations and maintenance of infrastructures, ensuring reliable network availability and full life-cycle approach;

– Infrastructure maintenance, regeneration and upgrading transport integration, interoperability and intermodality.

4.2.7. Clean Transport and Mobility

For the EU to reach its air quality, climate, and energy goals, including a 60% reduction in green-house gas emissions by 2050 as well as noise reduction, will require rethinking the whole mobility system including users, vehicles, fuels and infrastructures. It will also require the deployment of low-emission alternative energies and market uptake of zero-emission vehicles/vessels/aircrafts. In addition to the harmful effects of greenhouse gas emissions, transport contributes significantly to poor air quality and noise in Europe with negative consequences for the health of citizens[7]. Building on progress with electrification and the use of fuel cells for cars, buses and light duty vehicles it is essential to accelerate research and innovation solutions for other sectors such as aviation, maritime and inland navigation and lorries.

Broad Lines

– Electrification of all transport modes (e.g. batteries, fuel cells, hybridisation, etc.) including new technologies for vehicle/vessel/aircraft powertrains, fast charging/refuelling, energy harvesting and user-friendly and accessible interfaces with the charging infrastructure, ensuring interoperability and seamless services provision; development and deployment of competitive, safe, high-performing and sustainable batteries for low and zero-emission vehicles;

– Sustainable new fuels and new smart vehicles/vessels/aircraft for existing and future mobility patterns and supporting infrastructure; technologies and user-based solutions for interoperability and seamless services provision;

– Reducing the impact of mobility on the environment and human health.

4.2.8. Smart Mobility

Smart mobility will help ensure the efficiency, safety and resilience of door-to-door mobility and all its components, in particular by using digital technologies, advanced satellite navigation (EGNOS/Galileo), and artificial intelligence. New technologies will help to optimise the use and efficiency of transport infrastructure and networks, improving multi-modality and connectivity, optimising traffic management and enable innovative transport solutions and services, thus reducing congestion and negative environmental impacts, providing better mobility and logistics services for citizens and businesses. Connected and

[7] Around one-third of EU citizens live in urban areas with concentration levels of pollutants above legal thresholds

automated mobility together with the enabling infrastructure will improve efficiency and safety in all transport modes..

Broad Lines

- Digital network-and traffic management: advanced decision support systems; next generation traffic management (including multi-modal network and traffic management); contributing to seamless, multimodal and interconnected mobility for passengers and freight; use and limitations of big data; use of innovative satellite positioning/navigation (EGNOS/Galileo);
- Single European Sky: solutions for higher degrees of automation, connectivity, safety, interoperability, performance, emission reduction and service;
- Rail technologies and operations for a high-capacity, silent, interoperable, and automated railway system;
- Connected, cooperative and automated mobility systems and services, including technological solutions and non-technological issues.

4.2.9. Energy Storage

Massive, concentrated and decentralised storage solutions (comprising chemical, electrochemical, electrical, mechanical and thermal) for the energy system will increase efficiency, flexibility, technology independence and accessibility as well as the security of supply. Low-emission, decarbonised transport will require a growing share of electrical and/or other alternatively fuelled vehicles, with better-performing and cheaper, recyclable and reusable batteries, as well as local provision of synthetic/renewable fuels such as hydrogen and innovative solutions for on-site storage.

Broad Lines

- Technologies including liquid and gaseous renewable fuels and their associated value chains, for daily to seasonal energy storage needs;
- Batteries and the EU value chain, including design, large-scale battery cell production technologies, reuse and recycling methods;
- Low zero-carbon hydrogen including fuel cells, and the EU value chain from design to end use across various applications.

5. CLUSTER 'FOOD AND NATURAL RESOURCES'

5.1. Rationale

Human activities are exerting increasing pressure on soils, seas and oceans, water, air, biodiversity and other natural resources. Nourishing the planet's growing population is directly dependent on the health of natural systems and resources. However, combined with climate change, humanity's growing demand for natural resources creates environmental pressures that go far beyond sustainable levels, affecting ecosystems and their capacity to provide services for human well-being. The concepts of the circular economy, the bioeconomy and the blue economy provide an opportunity to balance environmental, social and economic goals and to set human activities on a path to sustainability.

Meeting the goals of sustainable development, guaranteeing the production and consumption of safe and healthy food, promoting sustainable practices in agriculture, aquaculture, fisheries and forestry, ensuring access to clean water, soil and air for all, cleaning up the seas and oceans, preserving and restoring the planet’s vital natural systems and environment requires that we harness the potential of research and innovation. But the pathways for the transition to sustainability and ways to overconme reslient barriers are hardly understood. Making the transition to sustainable consumption and production and restoring planetary health requires investing in technologies, new business models, and social and environmental innovation. This creates new opportunities for a sustainable, resilient, innovative and responsible European economy, boosting resource efficiency, productivity and competitiveness, and generating jobs and growth.

Activities will build a knowledge base and deliver solutions to: sustainably manage and use natural resources from land and sea - and enhance the role of terrestrial and aquatic systems as carbon sinks; ensure food and nutrition security, providing safe, healthy and nutritious diets; accelerate the transition from a fossil-based linear economy to a resource efficient, resilient, low emission, low-carbon circular economy, and supporting the development of a sustainable bio-based economy and the blue economy; and develop resilient and vibrant rural, coastal and urban areas.

They will help to maintain and enhance the provision of biodiversity and secure the long-term provision of ecosystem services, climate adaptation and carbon sequestration (both on land and sea). They will help reduce greenhouse gas (GHG) and other emissions, waste and pollution from primary production (both terrestrial and aquatic), processing, consumption and other human activities. They will trigger investments, supporting the shift towards a circular economy, bioeconomy and blue economy, whilst protecting environmental health and integrity.

They will also foster participatory approaches to research and innovation, including the multi-actor approach and develop knowledge and innovation systems at local, regional, national and European levels. Social innovation with citizens' engagement and trust in innovation will be crucial to encourage new governance, production and consumption patterns.

As these challenges are complex, interlinked and global in nature, activities will follow a systemic approach, cooperating with Member States and international partners, with other funding sources and with other policy initiatives. This will involve user-driven exploitation of

environmental big data sources, such as those from Copernicus, EGNOS/Galileo, INSPIRE, EOSC, GEOSS, CEOS, EMODnet.

Research and innovation activities under this Cluster contribute in particular to the implementation of the goals of: the Environmental Action Programme, the Common Agricultural Policy, the Common Fisheries policy, the Food Law legislation, the Maritime policy, the Circular Economy Action Plan, the EU Bioeconomy Strategy, and the 2030 climate and energy framework as well as EU legal provisions to reduce air pollution.

Activities will contribute directly to the following Sustainable Development Goals (SDGs) in particular: SDG 2 – Zero Hunger; SD 6 - Clean Water and Sanitation; SDG 11 – Sustainable Cities and Communities; SDG 12 - Responsible Consumption and Production; SDG 13 – Climate Action; SDG 14 – Life Below Water; SDG 15 - Life on Land.

5.2. Areas of intervention

5.2.1. Environmental Observation

The capacity to observe the environment underpins research and innovation[8] for the sustainable use and monitoring of food and natural resources. Improved spatio-temporal coverage and sampling intervals at reduced cost, as well as big data access and integration from multiple sources provide new ways to monitor, understand and predict the Earth system. There is a need for a wider deployment, exploitation and update of new technologies and continued research and innovation to address gaps in Earth Observation (EO) on land and sea and in the atmosphere, collaborating in particular through the Global Earth Observation System of Systems (GEOSS) and its European component EuroGEOSS.

Broad Lines

- User driven and systemic approaches including open data, to environmental data and information for complex modelling and predictive systems;
- Extension of the Copernicus product and service portfolio;
- Biodiversity status, ecosystem protection, climate mitigation and adaptation, food security, agriculture and forestry, land use and land use change, urban and peri-urban development, natural resources management, ocean exploitation and conservation, maritime security, and other relevant domains;
- User oriented applications including their scaling up, to contribute to the management of European natural resources and ecosystems services and their related value chain.

[8] Earth Observation will support research and innovation under other intervention areas within this Global Challenge as well as other relevant parts of Horizon Europe.

5.2.2. Biodiversity and Natural Capital

Improved understanding of biodiversity and ecosystems, the multiple services they provide and planetary 'boundaries' as well as solutions harnessing nature's power and complexity is needed to address societal challenges, to enhance sustainability and to attain the EU objective of 'Living well within the limits of our planet' by 2050 as laid down in the 7th EU Environmental Action Programme. Due account must be taken throughout whole value chains of potential upstream impacts. International cooperation and contribution to international efforts and initiatives, such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, are essential to achieve the objectives in this area. There is a need to better understand the governance of the transition to susntainability in the eceonomic, social and natural system, from the local to the global level.

Broad Lines

- The state and value of biodiversity, terrestrial and marine ecosystems, natural capital and ecosystem services;
- Holistic and systemic approaches within a socio-ecological framework for the links between biodiversity, ecosystems and ecosystems services and their causality relationships with drivers of change, across different scales and economic activities, including the governance of transition processes to sustainability;
- Modelling of trends and integrated scenarios for biodiversity, ecosystem services and good quality of life at different scales and horizons; the potential contribution of biotopes and ecosystems as carbon sinks under various climate change scenarios;
- Ecotoxicology of compounds and new pollutants, their interactions and environmental behaviour, and altered biochemical loops under changing climate;
- Mainstreaming biodiversity and ecosystem services in decision-making frameworks and accounting systems of governments and businesses, as well as quantification of their benefits;
- Adaptable and multi-functional nature-based solutions, addressing challenges in cities, rural and coastal areas related to climate change, natural disasters, biodiversity loss, ecosystem degradation, pollution, and citizens' health and well-being;
- Multi-actor living labs approaches engaging authorities, stakeholders, business and civil society in co-designing and co-creating systemic solutions for the preservation, restoration and sustainable use of natural capital the governance of the transition to sutainabilty and sustainable management options in economic activities throughout whole value loops.

5.2.3. Agriculture, Forestry and Rural Areas

Resilient and sustainable farming and forestry systems provide economic, environmental and social benefits in a changing context for primary production. In addition to contributing to food and nutrition security, they feed into dynamic value chains, manage land and natural

resources as well as deliver a range of vital public goods including carbon sequestration, biodiversity preservation, pollination and public health. Integrated approaches are needed to promote the multiple functions of agro- and forest (eco)systems taking into account the changing context for primary production, notably in relation to climate and environment, resource availability, demography and consumption patterns. It is also necessary to address the spatial and socio-economic dimension of agriculture and forestry activities and mobilise the potential of rural areas.

Broad Lines

- Methods, technologies and tools for sustainable and resilient production in farming and forestry;
- Sustainable management and efficient use of natural resources (e.g. soils, water, nutrients and biodiversity including genetic resources) in agriculture and forestry; alternatives to fossil-based resources and adoption of circular economy principles;
- Climate and environmental impact of activities in the primary sector; potential of agriculture and forestry as carbon sinks and for mitigation of greenhouse gas emissions including negative emissions approaches;
- Plant pests and diseases and animal health and welfare; alternatives to the use of contentious pesticides, antibiotics and other substances;
- Antimicrobial resistance and threats from biological and agrochemical hazards as well as chemical contaminants tackling the links between plant, animal , ecosystems and public health from One-Health and Global-Health perspectives;
- The use and delivery of ecosystems services in agriculture and forestry systems applying ecological approaches and testing nature-based solutions from farm to landscape levels for an environmentally friendly agriculture;
- Agricultural and forestry systems from farm to landscape levels; the use and delivery of ecosystem services in primary production;
- Innovations in farming at the interfaces between agriculture, aquaculture and forestry and in urban areas;
- Land use, rural development and territorial linkages; capitalising on the social, cultural, economic and environmental assets of rural areas for new services, business models, value chains and public goods;
- Digital innovations in farming, forestry and across value chains and rural areas through the use of data and development of infrastructures, technologies and governance models;
- Agricultural knowledge and innovation systems and their interconnection at various scales; advice, building skills and information sharing.

5.2.4. Sea and Oceans

Seas and oceans' natural capital and ecosystem services offer significant socio-economic and welfare benefits. This potential is at risk because of the severe pressure from human and natural stressors such as pollution, overfishing, climate change, sea-level rise and extreme weather events. To prevent seas and oceans from reaching a point of no return, it is necessary to strengthen our knowledge and understanding in order to sustainably manage, protect and restore marine and coastal ecosystems and prevent marine pollution, in a context of an improved and responsible ocean governance framework. This will also include research to sustainably unlock the vast and unexploited economic potential of seas and oceans aiming at producing more food without increasing pressures on them, and also contribute to alleviate pressure on land, freshwater and ocean resources. There is a need for partnering approaches, including sea basin and macro-regional strategies, extending beyond the EU (e.g. in the Mediterranean, the Baltic, the Black Sea, the Atlantic, the Caribbean Sea and in the Indian Ocean); and for contributing to International Ocean Governance commitments, initiatives like the United Nations Decade of Ocean Science for Sustainable Development and commitments linked to the conservation of marine biological diversity in areas beyond national jurisdiction.

Broad Lines

- Sustainable sea and ocean farming, fisheries and mariculture for food, including alternative sources of protein with increased food security, food sovereignty and climate resilience;
- Strengthened resilience of marine ecosystems thereby ensuring seas and ocean health, combating and mitigating the effects of natural and human pressures like pollution and plastics, eutrophication, acidification, seas and oceans warming, sea level rise, considering the intersection between land and sea and fostering a circular approach;
- Ocean governance at global and regional levels to ensure conservation and sustainable use of the seas and oceans resources;
- Technologies for the digital ocean (seafloor, water column and water surface) connecting services and communities in land-based, climate, space and weather related activities, and promoted through the Blue Cloud as part of the European Open Science Cloud;
- Monitoring and predictive/forecasting capacities including sea-level rise and other natural hazards e.g. storms surges, tsunamis;
- Blue value-chains, the multiple-use of marine space and growth of the renewable energy sector from seas and oceans, including sustainable micro- and macro- algae;
- Nature-based solutions based on marine and coastal ecosystem dynamics, biodiversity and multiple ecosystem services, which will enable systemic approaches to sustainably use the resources of seas and oceans, contribute to environmental protection, coastal management, and adaptation to climate change;
- Blue innovation including in the blue and digital economies, across coastline areas, coastal cities and ports in order to strengthen resilience of coastal areas and increase citizens' benefits.

– Better understanding of the role of oceans for climate change mitigation and adaptation.

5.2.5. Food Systems

The combined effects of population growth, resource scarcity and overexploitation, environmental degradation, climate change and migration create unprecedented challenges which require food system transformation (FOOD 2030).[9] Current food production and consumption are largely unsustainable while we are confronted with the double burden of malnutrition, characterised by the coexistence of undernutrition and obesity. Future food systems need to deliver sufficient safe, healthy and quality food for all, underpinned by resource efficiency, sustainability (including the reduction of GHG emissions, pollution and waste production), linking land and sea, reducing food waste, enhancing food production from the seas and oceans and encompassing the entire 'food value chain' from producers to consumers – and back again. This needs to go hand in hand with development of the food safety system of the future and the design, development and delivery of tools, technologies and digital solutions that provide significant benefits for consumers and improve the competitiveness and sustainability of the food value chain. Furthermore, there is a need to foster behavioural changes in food consumption and production patterns as well as to engage primary producers, industry (including SMEs), retailers, food service sectors, consumers, and public services. *Broad Lines*

– Sustainable and healthy diets for people's well-being across their lifespan;

– Personalised nutrition especially for vulnerable groups, to mitigate the risk factors for diet-related and non-communicable diseases;

– Consumers' behaviour, lifestyle and motivations, promoting social innovation and societal engagement for better health and environmental sustainability throughout the entire food value chain;

– Modern food safety and authenticity systems, enhancing consumer confidence in the food system;

– Food system mitigation of and adaptation to climate change, including the exploration of the potential and use of the microbiome, forgotten crops, alternative proteins;

– Environmentally sustainable, circular and resource efficient food systems from land and sea, towards zero food waste throughout the entire food system, through reuse of food and biomass, recycling of food waste, new food packaging, demand for tailored and local food;

– Innovation and food systems for place-based innovation and empowerment of communities, fostering fair trade and pricing, inclusiveness and sustainability through partnerships between industry, local authorities, researchers and society.

[9] SWD(2016) 319 final: European Research and Innovation for Food and Nutrition Security

5.2.6. Bio-based Innovation Systems

Bio-based innovation lays the foundations for the transition away from a fossil-based economy by encompassing the sustainable sourcing, industrial processing and conversion of biomass from land and sea into bio-based materials and products. It also capitalises on the potential of living resources, life sciences and industrial biotechnology for new discoveries, products and processes. Bio-based innovation, including technologies, can bring new economic activities and employment to regions and cities, contribute to revitalising rural and coastal economies and strengthen the circularity of the bioeconomy.

Broad Lines

- Sustainable biomass sourcing and production systems, focusing on high-value applications and uses, social and environmental sustainability, impact on climate and biodiversity reduction targets and overall resource efficiency;
- Life sciences and their convergence with digital technologies for prospecting, understanding and sustainably use biological resources;
- Bio-based value chains, materials, including bio-inspired materials, products and processes with novel qualities, functionalities and improved sustainability (including reducing greenhouse gases emissions), fostering the development of advanced biorefineries using a wider range of biomass;
- Biotechnology, including cross sectoral cutting-edge biotechnology, for application in competitive, sustainable and novel industrial processes, environmental services and consumer products[10];
- Circularity of the bio-based economy through technological, systemic, social and business model innovation to radically increase the value generated per unit of biological resources, keeping the value of such resources in the economy for longer and supporting the principle of the cascading use of sustainable biomass through research and innovation;
- Inclusive bioeconomy patterns with different actors participating in the creation of value, maximising societal impact.
- Increased understanding of the boundaries of the bio-based economy and its synergies and trade-offs with a healthy environment.

5.2.7. Circular Systems

Circular production and consumption systems will provide benefits to the European economy by reducing resource dependency and increasing the competitiveness of enterprises, and to European citizens by creating new job opportunities and reducing pressures on the environment and climate. Beyond industrial transformation, the transition to a low-emission, resource efficient and circular economy will also need a broader system shift that requires systemic eco-innovative solutions, new business models, markets and investments, enabling infrastructure, social innovation changes in consumer behaviour, and governance models stimulating multi-stakeholder collaboration to ensure that the intended system change

[10] Health biotechnology applications will be addressed by the Health cluster under this pillar.

achieves better economic, environmental and social outcomes[11]. Opening for international cooperation will be important for comparability, generating and sharing knowledge and avoiding duplication of efforts, e.g. through international initiatives such as the International Resource Panel.

Broad Lines

- Systemic transition to a resource-efficient and circular economy, with new paradigms in consumer interaction, new business models for resource efficiency and environmental performance; products and services stimulating resource efficiency during the whole lifecycle; systems for sharing, reuse, repair, remanufacturing, recycling and composting;
- Metrics and indicators for measuring the circular economy and life cycle performance; governance systems which accelerate expansion of the circular economy and resource efficiency while creating markets for secondary materials; multi-stakeholder and cross-value chain collaboration; instruments for investment in the circular economy;
- Solutions for sustainable and regenerative development of cities, peri-urban areas and regions, integrating the circular economy transformation with nature-based solutions, technological, digital, social, cultural and territorial governance innovations;
- Eco-innovation for prevention and remediation of environmental pollution from hazardous substances and chemicals of emerging concern; looking also at the interface between chemicals, products and waste;
- Circular use of water resources, including reduction of water demand, prevention of losses, water reuse, recycling and valorisation of wastewater and governance models for smart water allocation, addressing sources of pollution and tackling other pressures on water resources.

[11] The activities in Circular Systems Area of Intervention are complementary to those of Low-Carbon and Clean Industry in the Digital and Industry cluster.

6. NON-NUCLEAR DIRECT ACTIONS OF THE JOINT RESEARCH CENTRE

6.1. Rationale

High-quality and trusted scientific evidence is essential for good public policies. New initiatives and proposals for EU legislation need transparent, comprehensive and balanced evidence, whereas implementation of policies needs evidence to measure and monitor their impact and progress.

The JRC adds value to EU policies because its science is excellent, multi-disciplinary and independent of national, private and other external interests. Serving all areas of EU policy, it provides the cross-sectoral support that policymakers need to tackle increasingly complex societal challenges. The JRC's independence from special interests combined with its scientific-technical reference role enable it to facilitate consensus building between stakeholders and policy makers and to help diffusing sensitive situations. With its capacity to respond rapidly to policy needs, the JRC's activities are complementary with indirect actions aiming at supporting longer term policy objectives.

The JRC performs its own research and is a strategic manager of knowledge, information, data and competences to deliver high quality and relevant evidence for smarter policies. To achieve this, the JRC works together with the best organisations world-wide, and with international, national and regional stakeholders. Its research contributes to the general objectives and priorities of Horizon Europe and is focussed on European policy priorities, supporting a Europe that is safe and secure, prosperous and sustainable, social and stronger on the global scene.

6.2. Areas of intervention

6.2.1. Strengthening the knowledge base for policy making

Knowledge and data are growing exponentially. If policy makers are to make sense and use of this they must be reviewed and filtered. There is also a need for cross-cutting scientific methods and analytical tools for use by all Commission services, especially to anticipate upcoming societal challenges and support better regulation. This includes innovative processes to engage stakeholders and citizens in policy-making issues.

Broad Lines

- Modelling, micro-economic evaluation, risk assessment methodologies, quality assurance tools for measurements, design of monitoring schemes, indicators and scoreboards, sensitivity analysis and auditing, lifecycle assessment, data and text mining, (big) data analytics and applications, design thinking, horizon scanning, anticipation and foresight studies, behavioural research, and stakeholders and citizen engagement;
- Knowledge and competence centres;
- Communities of practice and knowledge sharing platforms;
- Data management, data sharing and coherence.

6.2.2. Global Challenges

The JRC will contribute to the specific EU policies and commitments addressed by the five Global Challenges clusters, notably the EU's commitment to the Sustainable Development Goals.

Broad Lines

1. Health

- Scientific and technical policy support for improved public health and health care systems, including medical devices and health technology assessments, databases, digitisation;
- Safety assessment methods for potential health and environmental risks posed by chemical substances and pollutants;
- EU Reference Laboratory for Alternatives to Animal Testing;
- Quality assurance tools such as certified reference materials for health biomarkers;
- Research on newly emerging health issues and health threats.

2. Inclusive and secure society

- Research on inequality, poverty and exclusion, social mobility, cultural diversity, and skills; assessment of social, demographic and technological transformations on the economy and on society;
- Support to the preservation of cultural heritage;
- Knowledge centre for migration and demography;
- Knowledge centre for disaster risk management;
- Support to security policies in the areas of protection of critical infrastructures and public spaces, CBRN-E (Chemical, Biological, Radiological, Nuclear, and Explosive materials) and hybrid threats, border protection and document security, and information and intelligence for countering terrorism;
- Technologies for CBRN-E materials detection, biometric systems, and intelligence-gathering techniques;
- Support to the EU's security position in the world; assessment of competitiveness and innovation of the Union defence industry; exploitation of security-defence synergies;
- Research for reinforced Cybersecurity capabilities, cyber-resilience, and cyber-deterrence.

3. Digital and Industry

- Implications of digitisation, with a focus on new and emerging ICT technologies such as machine learning and artificial computing, distributed ledgers, Internet of Things, and High-Performance Computing;
- Digitisation in individual sectors, such as energy, transport, construction, health and government;
- Industrial metrology and quality assurance tools for smart manufacturing;

- Research on nanotechnology and other Key Enabling Technologies;
- Research on best available techniques and environmental management practices, techno-economic analyses and life cycle assessment of industrial processes, waste management, water reuse, raw materials, critical raw materials and quality criteria for recovered materials, all supporting circular economy;
- Implementation of Copernicus actions;
- Technical and scientific support for applications of the EU Global Navigation Satellite System Programmes.

4. Climate, Energy and Mobility

- Support to implementation of the EU climate, energy and transport policies, transition to a low-carbon economy and strategies for decarbonisation towards 2050; analysis of integrated national climate and energy plans; assessment of decarbonisation pathway in all sectors, including agriculture and Land Use Land Use Change and Forestry;
- Assessment of risks in vulnerable ecosystems and critical economic sectors and infrastructure, with focus on adaptation strategies;
- Analysis of the R&I dimension of Energy Union; assessment of EU competitiveness in the global clean energy market;
- Assessment of deploying renewables and clean energy production technologies;
- Analysis of energy use of buildings, smart and sustainable cities, and industries;
- Technical and socio-economic analysis of energy storage, particularly sector coupling and batteries;
- Analysis of the EU's energy security of supply, including energy infrastructure, and energy markets;
- Support to energy transition, including the Covenant of Mayors, clean energy for EU Islands, sensitive regions, and Africa;
- Integrated analysis for deployment of Cooperative, Connected and Automated Mobility;
- Integrated analysis for development and deployment of the next generation of battery technologies;
- Harmonised test procedures and market surveillance for CO2 and air pollutant emissions from vehicles, assessment of innovative technologies;
- Assessment of smart transport, traffic management systems and congestion indicators;
- Analyses of alternative fuels and related infrastructure needs.

5. Food and Natural Resources

- Research on land, soil, forests, air, water, marine resources, raw materials and biodiversity to support the effective preservation, restoration and sustainable use of natural capital, including sustainable resources management in Africa ;

– Knowledge centre for global food nutrition security;
– Assessment of climate change and potential mitigation and adaptation measures for agricultural and fisheries policies, including food security;
– Monitoring and forecasting of agricultural resources in EU and neighbourhood countries;
– Research for sustainable and economically thriving aquaculture and fisheries, and for Blue Growth and the Blue Economy;
– Validated methods, laboratory proficiency tests and new analytical tools for implementing food safety policies;
– EU Reference Laboratories on Feed Additives, Genetically Modified Organisms and Food Contact Materials;
– Knowledge centre for food fraud and quality;
– Knowledge centre for bioeconomy.

6.2.3. Innovation, economic development, and competitiveness

The JRC will contribute to innovation and technology transfer.. It will support the functioning of the internal market and the economic governance of the Union. It will contribute to development and monitoring of policies targeting a more social and sustainable Europe. It will support the EU's external dimension and international goals and help in promoting good governance. A well-functioning internal market with a strong economic governance and fair social system will foster innovation and competitiveness.

Broad Lines

– Analysis of innovation policies;
– Economic, financial and fiscal analysis;
– Pre-normative research and testing for harmonisation and standardisation;
– Production of certified reference materials;
– Market surveillances activities;
– Management of intellectual property rights;
– Promotion of technology transfer cooperation.

6.2.4. Scientific Excellence

The JRC shall pursue excellence in research and extensive collaboration with top level research institutions worldwide. It will carry out research in emerging fields of science and technology and promote open science and open data as well as knowledge transfer.

Broad Lines

– Exploratory research programmes;
– Dedicated collaborative and exchange programmes with research institutions and scientists;

– Access to JRC research infrastructures;

– Training of scientists and national experts;

– Open science and open data.

6.2.5. Territorial development and support for Member States and Regions

The JRC will contribute to regional and urban policies, with focus on innovation-led territorial development, and with a view to reducing disparities between regions. It will also offer technical assistance to Member States and third countries and support the implementation of European legislation and actions.

Broad Lines

– Implementation of regional and urban policies, smart specialisation strategies, strategies for economic transformation of regions in transition, integrated urban development strategies and data;

– Capacity building of local and regional actors for implementation of macro-regional strategies;

– Knowledge centre for territorial policies;

– 'On demand' advice and tailored support to Member States, regions or cities, including through a virtual network of Science4Policy Platforms.

PILLAR III

OPEN INNOVATION

Open innovation is a vital paradigm for the EU to continue delivering prosperity to its citizens and meeting challenges of the future. Implementing it requires a systemic, cross-cutting and multifaceted approach. Europe's economic progress, social welfare and quality of life rely on its ability to boost productivity and growth, which, in turn, depends heavily on its ability to innovate. Innovation is also key to solving the major challenges that lie ahead for the EU.

Like its predecessors, Innovation is at the heart of Horizon Europe. The quest for new ideas, products and processes is driving Horizon Europe objectives and implementing modalities, from strategic programming to calls, and is present from the onset to the end of any project supported, from 'blue-sky' research to industrial or technological roadmaps and missions.

Yet, innovation deserves specific measures, as the EU must decisively enhance the conditions and environment European innovation can thrive, so that ideas are quickly shared between actors in the innovation ecosystem, and new ideas and technologies swiftly transformed into the products and services needed for the EU to deliver.

Recent decades have seen the emergence of major and global new markets in entertainment, media, health care, lodging and retail, based on breakthrough innovations in ICT, biotech, internet and the platform economy. These market-creating innovations, which impact the EU economy as a whole, are deployed by fast growing and often new companies. But only a few originate in the EU.

A new global wave of breakthrough innovation is coming up, one that will be based on more 'deep-tech' technologies such as block-chain, artificial intelligence, genomics and robotics, and other technologies, which may also emerge from individual innovators and communities of citizens. They have in common that they are taking shape at the intersection between different technologies, industry sectors and scientific disciplines, offering radically new combinations of products, processes, services and business models, and have the potential to open up new markets worldwide. Additional sectors such as manufacturing, financial services, transport or energy will also be impacted.

Europe has to ride that wave. It is well positioned as the new wave comes in 'deep-tech' areas, such as artificial intelligence, quantum technologies, clean energy sources, where Europe has some competitive advantages regarding science and knowledge, and can build on close public-private cooperation (e.g. in health care or energy).

For Europe to lead that new wave of breakthrough innovation, the following underlying challenges need to be met:

– Improve the transformation of science into innovation in order to accelerate the transfer of ideas, technologies and talent from the research base into start-ups and industry;

– Speed up industrial transformation: European industry is lagging behind in embracing new technologies and scaling up: 77% of the young and big R&D companies are in US or Asia and only 16% are based in Europe;

– Increase risk finance to overcome financing gaps: Europe's innovators suffer from a low supply of risk finance. Venture capital is key to turning breakthrough innovations into world-leading companies but, in Europe, it is less than a quarter of the amounts raised in the US and in Asia. Europe must bridge the 'Valleys of death', whereby ideas and innovations fail to reach the market due to the gap between public support and private investment, in particular with regard to high-risk breakthrough innovations and long-term investments;

– Enhance and simplify the European landscape for funding and supporting research and innovation: the multitude of funding sources provides a complex landscape for innovators. EU intervention has to cooperate and coordinate with other initiatives at European, national and regional level, public and private, to better enhance and align supporting capacities, and provide for an easy-to-navigate landscape for any European innovator;

– Overcome fragmentation to the innovation ecosystem. While Europe is home to a growing number of hotspots, these are not well connected. Companies with international growth potential have to cope with fragmentation of national markets with their diverse languages, business cultures and regulations.

In order to cope with that new global wave of breakthrough innovation, EU support to breakthrough innovators requires an agile, simple, seamless and tailored approach. Policy to develop and deploy breakthrough innovations and scale-up companies has to be bold in taking risks and must take into account the above-mentioned challenges and add value to related innovation activities implemented by individual Member State.

Horizon Europe's Open Innovation pillar, in cooperation with other EU policies and in particular the InvestEU Programme, is designed to deliver such tangible results. It builds on lessons learned and on experience gained under the previous framework programmes, in particular from activities targeting future technologies and innovation (such as Future Emerging Technologies (FET) and Fast Track to Innovation (FTI)), SMEs (such as the SME Instrument), but also private and corporate finance (such as FP7 RSFF, Horizon 2020 InnovFin), all part of the 'EIC pilot' activities launched for the period 2018-2020.

Based on these experiences, this Pillar provides for the launch of the European Innovation Council (EIC), which will promote breakthrough innovation with rapid scale-up potential at global level and with dedicated types of actions and activities:

– Supporting the development of future and emerging breakthrough innovations;

– Bridging financing gaps in the development, deployment and scaling up of market-creating innovations;

– Increasing the impact and visibility of EU innovation support.

Whilst the EIC will directly support breakthrough innovations, the overall environment from which European innovations nurture and emerge must be further developed and enhanced: it must be a common European endeavour to support innovation all across Europe, and in all dimensions and forms, including through complementary EU and national policies and resources whenever possible. Hence, this Pillar provides also for:

– Renewed and reinforced coordination and cooperation mechanisms with Member States and Associated Countries, but also with private initiatives, in order to support all types of European innovation ecosystems and their actors;

– Support to the European Institute of Innovation and Technology (EIT) and Knowledge and Innovation Communities (KICs).

Additionally, as a continued effort to enhance risk-finance capacities for research and innovation in Europe and where necessary, this pillar will link with the InvestEU programme. Building on the successes and the experiences gained under Horizon 2020 InnovFin, as well as under EFSI, the InvestEU Programme will enhance access to risk finance for bankable research organisations, innovators and entrepreneurs, in particular for SMEs and small midcaps, as well as for investors.

1. THE EUROPEAN INNOVATION COUNCIL (EIC)

1.1. Areas of Intervention

The objective of the EIC is to identify, develop and deploy breakthrough and disruptive innovations (including technologies), and support the rapid scale-up of innovative firms at EU and international levels along the pathway from ideas to market.

The EIC will be implemented primarily through two complementary types of action, namely *the Pathfinder for advanced research*, for the early stages of technology development, and *the Accelerator* for innovation and market deployment actions, including the pre-mass commercialisation stages and company growth. With the idea to offer a single one-stop shop and a single process of support, the *Accelerator* will also award blended finance, combining grants with equity investments. It will in addition also channel access to loans provided under the InvestEU programme.

These two complementary types of actions will share common characteristics. They will:

– Focus on breakthrough and disruptive innovations, including social, that have the potential to create new markets, as opposed to those which make incremental improvements in existing products, services or business models;

– Be mainly bottom-up, open to innovations from all fields of science, technology and applications in any sector, while also enabling targeted support for emerging breakthrough or disruptive technologies of potential strategic significance;

– Innovations that cut across different scientific, technological (e.g. combining physical and digital) fields and sectors will be encouraged;

– They will be centred on innovators, simplifying procedures and administrative requirements, making use of interviews to help assess applications, and ensuring fast decision making;

– They will support high-risk innovations where the risks, whether technological, market and/or regulatory, cannot be borne by the market alone or exclusively supported by financial instruments under InvestEU.

– They will be managed pro-actively with milestones to gauge progress and the possibility to reorient projects where needed.

As well as financial support, innovators will have access to EIC business advisory services providing to projects coaching, mentoring and technical assistance, and pairing innovators with peers, industrial partners and investors. Innovators will also have facilitated access to expertise, facilities (including innovation hubs [12]) and partners from across EU supported activities (including those of the EIT, in particular through its KICs).

[12] These are public or private facilities that offer access to latest knowledge and expertise on digital and related enabling technologies necessary for companies to become more competitive with regard to production, services and business processes.

Particular attention will be paid to ensuring proper and efficient complementarity with individual or networked Member States initiatives, including in the form of European Partnership.

1.1.1. The Pathfinder for Advanced Research

The *Pathfinder's* will provide grants to high-risk cutting-edge projects exploring new territories aiming to develop into potentially radical innovative technologies of the future and new market opportunities. It will build on the experience from the Future and Emerging Technology (FET) schemes supported under FP7 and Horizon 2020, including the Horizon 2020 FET-Innovation Launchpad, as well as the Horizon 2020 SME Instrument Phase 1.

The *Pathfinder* overall objective will be to nurture potential market creating innovation out of breakthrough technological ideas, and bring them to demonstration stage or development of business cases or strategies for further take-up by the *Accelerator* or any other market deployment solution. To that end, the *Pathfinder* will initially support the earliest stages of scientific and technological research and development, including proof of concept and prototypes for technology validation.

In order to be fully open to broad-sweeping explorations, opportunities of serendipity and unexpected ideas, concepts and discoveries, the *Pathfinder* will be mainly implemented through a continuous open call for bottom-up proposals. The *Pathfinder* will also provide for competitive challenges to develop key strategic objectives[13] calling for deep-tech and radical thinking. Regrouping of selected projects into thematic or objective driven portfolios will allow establishing critical mass of efforts and structuring new multidisciplinary research communities.

These portfolios of selected projects[14] will be further developed and enhanced, each along a vision developed with their innovators, but also shared with the research and innovation community at large. The *Pathfinder's Transition activities* will be implemented to help innovators develop the pathway to commercial development, such as demonstration activities and feasibility studies to assess potential business cases, and support the creation of spin offs and startups. These *Pathfinder's Transition activities* may also consist of complementary grants to top-up or enlarge the scope of previous and on-going actions, to bring in new partners, to enable collaboration within the portfolio and to develop its multidisciplinary community.

The *Pathfinder* will be open to all types of innovators, from individuals to universities, research organisations and companies, in particular startups and SMEs, and from single beneficiaries to multi-disciplinary consortia. In the case of single beneficiary projects, larger companies will not be permitted. The *Pathfinder* will be implemented in close coordination with other parts of Horizon Europe, in particular with the European Research Council (ERC),

[13] These could include topics such as Artificial Intelligence, Quantum technologies, Biocontrol or Second generation digital twins, or any other topics identified in the context of the Horizon Europe Strategic programming (including with Member States' networked programmes).

[14] These may also include projects selected under Horizon 2020 programmes such as FET. These may also include other EU supported relevant activities and funded Seal of Excellence stemming from *Pathfinder* calls.

the Marie Skłodowska-Curie Actions (MSCA), and the Knowledge and Innovation Communities (KICs) of the European Institute of Innovation and Technology (EIT) activities. It will also be implemented in close coordination with Member States programmes and activities.

1.1.2. The Accelerator

Available private and corporate financing remains scarce between late stage of research and innovation activities and market take-up for high-risk breakthrough and market-creating innovations. In order to bridge the 'valley of death', in particular for 'deep tech' innovations that are key to Europe's future growth, public support must develop a radically new approach. Where the market does not provide viable financial solutions, public support should provide for a specific risk-sharing mechanism, bearing more if not all of the initial risk of potential breakthrough market-creating innovations to attract alternate private investors in a second stage, as operations unfold and the risk is lowered.

Consequently the *Accelerator* will provide financial support to not yet 'bankable' or investors-attractive innovators and companies that have the ambition to develop and deploy in EU and international markets their breakthrough innovations and to scale up rapidly. For that purpose it will build on the experience from the Phases 2 and 3 of Horizon 2020 SME Instrument and from Horizon 2020 InnovFin, in particular through the addition of non-grant components and the ability to support larger and longer investments.

The *Accelerator* will provide support in the form of EIC blended finance, a mix of:

– Grant or reimbursable advance[15], to cover innovation activities;

– Support for investment in equity[16] or other repayable forms, so as to bridge innovation activities with effective market deployment, including scale-up, in a manner that does not crowd out private investments or distorts competition in the internal market. When relevant it will channel the innovator to access to debt financing (e.g. loans) provided by the InvestEU programme.

Support will be awarded through a single process and with a single decision, providing the supported innovator with a single global commitment to financial resources covering the various stages of innovation down to market deployment including pre-mass commercialisation. The full implementation of the awarded support will be subject to milestones and review. The combination and volume of financing will be adapted to the needs of the firm, its size and stage, the nature of the technology/innovation and the length of the innovation cycle. It will cover financing needs until replacement by alternative sources of investment.

For innovations with high technological risks ('deep tech') the support will always include a grant component covering the innovation activities. Where the various risks are reduced

[15] Reimbursable advance shall be paid back to the EU on an agreed schedule or be transformed into equity, if the beneficiary so choses.

[16] Usually no more than 25% of the voting rights. In exceptional cases, the EU may secure the acquisition of a blocking minority to protect European interests in essential areas, e.g. cyber security.

(technological, market, regulatory, etc.), the relative importance of the reimbursable advance component is expected to increase.

While the EU may bear alone the initial risk of selected innovation and market deployment actions, the aim will be to de-risk these and stimulate, from the on-set and during the development of the action, co-investments from alternative sources and even substitutive investors. Where relevant, milestones will establish co-investment objectives. Once de-risked and meeting the conditions established under Article 209(2) of the Financial Regulation, operations will be proposed for support to implementing partners under InvestEU.

The *Accelerator* will mainly operate through a continuously open and bottom-up call, targeting individual entrepreneurs (mainly start-ups and SMEs), with a particular attention paid to young and to women innovators. This open and bottom-up call will be complemented by targeted support for on emerging breakthrough or disruptive technologies of potential strategic significance. Proposals may also be submitted by investors, including public innovation agencies, but the support will be awarded to the company.

The *Accelerator* will allow for fast-track take-up of innovations stemming from Pathfinder-supported projects from the *Pathfinder*, from similar Member States 'advanced research programmes' and from other pillars of the EU Framework Programmes[17], in order to support them to reach the market. This identification of projects supported in other pillars of Horizon Europe and also previous Framework Programmes will be based on pertinent methodologies, such as the Innovation Radar.

1.1.3. Additional EIC activities

Additionally, EIC will also implement:

– EIC business acceleration services in support of *Pathfinder* and *Accelerator* activities and actions. The aim will be to connect the EIC Community of funded innovators, including funded Seal of Excellence, to investors, partners and public buyers. It will provide a range of coaching and mentoring services to EIC actions. It will provide innovators with access to international networks of potential partners, including industrial ones, to complement a value chain or develop market opportunities, and find investors and other sources of private or corporate finance. Activities will include live events (e.g. brokerage events, pitching sessions) but also, the development of matching platforms or use of existing ones, in close relation with financial intermediaries supported by the InvestEU and with the EIB Group. These activities will also encourage peer exchanges as a source of learning in innovation ecosystem, making particular good use of Members of the High Level Advisory board of the EIC and EIC Fellows;

[17] Such as ERC Proof of Concept, from projects supported under the 'Global Challenges and Industrial Competitiveness" Pillar, startups emerging from the KICs of the European Institute of Innovation and Technology, … Including from Horizon 2020 activities, particularly project selected under Horizon 2020 SME Phase 2 and related Seal of Excellence financed by Member States, (existing and future) European Partnerships.

– EIC Fellowship to honour the EU's leading innovators. They will be awarded by the Commission on the advice of the High Level Advisory Board to recognise them as ambassadors for innovation;

– EIC Challenges, i.e. inducement prizes, to help develop novel solutions to global challenges, bring in new actors and develop new communities. EIC recognition prizes will include iCapital, the Social Innovation Inducement Prize, and the Women Innovators' Prize.[18] The design of its prizes will be linked to EIC to other parts of the Framework programme, including missions and other funding bodies. Opportunities for cooperation with organisations (such as enterprises, universities, research organisations, business accelerators, charities and foundations) will be explored.

– EIC Innovative Procurement, to procure prototypes, or develop first purchase programme to facilitate the testing and acquisition of pre-market innovative technologies by public entities.

1.2. Implementation

The implementation of the EIC calls for the deployment of specific management features, to reflect its innovator-centric approach and types of actions.

1.2.1. The EIC Board

The High Level Advisory Board of the EIC (*EIC Board*) will assist the Commission in implementing the EIC. As well as advising on the EIC work programmes, the EIC Board will take an active role in advising the management and following up actions. It will have a communication function, with members playing an ambassadorial role helping to stimulate innovation in the EU. Communication channels will include attendance at key innovation events, social media, constitution of an EIC community of innovators, engaging with key media with a focus on innovation, common events with incubators and acceleration hubs.

The EIC Board will provide recommendations to the Commission regarding innovation trends or initiatives needed to enhance and foster the EU innovation ecosystem, including potential regulatory barriers. The Board's advice should also identify emerging areas of innovation to be taken into account in the activities under the Global Challenges and Industrial Competitiveness pillar and missions. In this way, the Board is expected to contribute to the overall coherence of the Horizon Europe programme.

1.2.2. EIC programme managers

The Commission will take a pro-active approach to the management of high risk projects, through access to the necessary expertise.

The Commission will appoint on a temporary basis a number of EIC programme managers to assist it with technology-based vision and operational guidance.

[18] The EIC prizes will take over the management of prizes launched under Horizon 2020 and provide for the design and implementation of new inducement prizes and recognition awards.

Programme managers will come from multiple spheres, including companies, universities, national laboratories and research centers. They will bring deep expertise from personal experience and years in the field. They will be recognised leaders, either having managed multidisciplinary research teams or directing large institutional programs, and know the importance of communicating their visions tirelessly, creatively, and broadly. Lastly, they will have experience in overseeing important budgets, which require sense of responsibility.

Programme managers will be expected to boost the impact of EIC funding by fostering an « active management » culture, a hands-on approach involving development at portfolio and projects levels of vision-based budgets, timelines and milestones EIC projects must meet to receive continued funding.

In particular, programme managers will oversee the implementation of *Pathfinder* calls, and propose evaluation rankings in view of consistent strategic portfolio of projects, expected to make essential contributions to the emergence of potential societal or economic market creating innovations.

Programme managers will have the task of nurturing *Pathfinder* portfolios by developing together with beneficiaries a common vision and a common strategic approach that leads to a critical mass of effort. This will involve building up and structuring of new communities, with the objective of bringing transforming breakthrough ideas into genuine and mature market creating innovations. Programme managers will implement *transition activities*, further developing portfolio with additional activities and partners, and closely monitoring potential spin-offs and start-ups.

Programme managers will review *Pathfinder* and *Accelerator*'s projects, for each milestone or at relevant intervals, to assess whether they should be continued, reoriented or terminated according to defined methods and procedures for project management. Such assessments may involve external experts.

Given the high risk nature of the actions, it is expected that a significant number projects will not reach completion. Budget decommitted from such terminations will be used to support other EIC actions.

1.2.3. Implementation of the EIC blended finance

The Commission will manage all operational elements of Accelerator projects, including the grant or other non-repayable forms of support.

For the purpose of managing EIC blended finance, the Commission may make use of indirect management, or where this is not possible, may establish a special purpose vehicle (EIC SPV). The Commisison shall seek to ensure the participation of other public and private investors. Where this is not possible at the initial set up, the special purpose vehicle will be structured in such a way that it can attract other public or private investors in order to increase the leverage effect of the Union contribution.

The EIC SPV will proactively leverage from the on-set co- and alternate public and private investments into individual *Accelerator's* operations and the SPV, perform due diligence, and negotiate technical terms of each investment in compliance with the priciples of additionality

and prevention of conflict of interests with other activities of the entities or counterparts. The EIC SPV will also define and implement an exit strategy for equity participation, which may include proposing to implementing partners financing under InvestEU, where appropriate and for operations whose risks have been sufficiently lowered so that they meet criteria of Article 209(2) of the Financial Regulation.

2. EUROPEAN INNOVATION ECOSYSTEMS

2.1. Rationale

To fully harness the potential of innovation involving researchers, entrepreneurs, industry and society at large, the EU must improve the environment within which innovation can flourish at all levels. This will mean contributing to the development of an effective innovation ecosystem at EU level, and encouraging cooperation, networking, and the exchange of ideas, funding and skills among national and local innovation ecosystems.

The EU must also aim to develop ecosystems that support social innovation and public sector innovation, in addition to innovation in private enterprises. Indeed, the government sector must innovate and renew itself in order to be able to support the changes in regulation and governance required to support the large-scale deployment of new technologies and a growing public demand for the more efficient and effective delivery of services. Social innovations are crucial to enhance the welfare of our societies.

2.2. Areas of intervention

As a first step the Commission will organise an EIC Forum of Member States and Associated countries' public authorities and bodies in charge of national innovation policies and programmes, with the aim of promoting coordination and dialogue on the development of the EU's innovation ecosystem. Within this EIC Forum, the Commission will:

– Discuss the development of innovation-friendly regulation, through the continued application of the Innovation Principle and development of innovative approaches to public procurement including developing and enhancing the Public Procurement of Innovation (PPI) instrument to drive innovation. The Observatory of Public Sector Innovation will also continue to support internal government innovation efforts, alongside the revamped Policy Support Facility;

– Promote the alignment of research and innovation agendas with EU efforts to consolidate an open market for capital flows and investment, such as the development of key framework conditions in favour of innovation under the Capital Markets Union;

– Enhance coordination between national innovation programmes and the EIC, so as to stimulate operational synergies and avoid overlap, by sharing data on programmes and their implementation, resources and expertise, analysis and monitoring of technological and innovation trends, and by interconnecting respective innovators' communities;

– Establish a joint communication strategy on innovation in the EU. It will aim at stimulating the EU's most talented innovators, entrepreneurs, particularly young drivers, SMEs and start-ups, also from fresh corners of the EU. It will stress the EU added-value that technical, non-technical, and social innovators can bring to EU citizens by developing their idea/vision into a thriving enterprise (social value/impact, jobs and growth, societal progression).

Activities will be implemented to ensure effective complementarity between EIC's types of action and their specific focus on breakthrough innovation, with activities implemented by Member States and Associated Countries, but also by private initiatives, in order to support all types of innovation, reach out to all innovators across the EU, and provide them with enhanced and adequate support.

To that end, the EU will:

– Promote and co-fund joint innovation programmes managed by authorities in charge of public national, regional or local innovation policies and programmes, to which private entities supporting innovation and innovators may be associated. Such demand-driven joint programmes may target, among others, early stage and feasibility study support, academia-enterprise cooperation, support to high-tech SMEs' collaborative research, technology and knowledge transfer, internationalisation of SMEs, market analysis and development, digitalisation of low-tech SMEs, financial instruments for close to market innovations activities or market deployment, social innovation. They may also include joint public procurement initiatives, enabling innovations to be commercialised in the public sector, in particular in support of the development of new policy. This could be particularly effective to stimulate innovation in public service areas and to provide market opportunities to European innovators.

– Support also joint programmes for mentoring, coaching, technical assistance and other services that are delivered close to innovators, by networks such as Enterprise Europe Network (EEN), clusters, pan-European platforms such as Startup Europe, local innovation actors, public but also private, in particular incubators and innovation hubs that could moreover be interconnected to favour partnering between innovators. Support may also be given to promote soft skills for innovation, including to networks of vocational institutions and in close relation with the European Institute of Innovation and Technology;

– Improve data and knowledge about innovation support, including mapping of support schemes, establishing data sharing platforms, benchmarking and evaluation of support schemes;

The EU will also launch actions necessary to further monitor and nurture the overall innovation landscape and innovation management capacity in Europe.

The ecosystem support activities will be implemented by the Commission, supported by an executive agency for the evaluation process.

3. EUROPEAN INSTITUTE OF INNOVATION AND TECHNOLOGY (EIT)

3.1. Rationale

As the report of the High Level Group on maximising the impact of EU research and innovation (the Lamy High level Group) clearly states, the way forward is 'to educate for the future and invest in people who will make the change'. In particular, European universities are called to stimulate entrepreneurship, tear down disciplinary borders and institutionalise strong non-disciplinary academia-industry collaborations. According to recent surveys, access to talented people is by far the most important factor influencing the location choices of European founders of start-ups. Entrepreneurship education and training opportunities play a key role in cultivating future innovators and in developing the abilities of existing ones to grow their business to greater levels of success. Access to entrepreneurial talent, together with access to professional services, capital and markets on the EU level, and bringing key innovation actors together around a common goal are key ingredients for nurturing an innovation ecosystem. There is a need to coordinate efforts across the EU.in order to create a critical mass of interconnected EU-wide entrepreneurial clusters and ecosystems,

Efforts are still needed to develop ecosystems where researchers, innovators, industries and governments can easily interact. Innovation ecosystems, in fact, still do not work optimally due to a number of reasons such as:

– Interaction among innovation players is still hampered by organizational, regulatory and cultural barriers between them;

– Efforts to strengthen innovation systems lack coordination and a clear focus on specific objectives and impact.

To address future challenges, embrace the opportunities of new technologies and contribute to sustainable economic growth, jobs, competitiveness and the well-being of Europe’s citizens, there is the need to further strengthen Europe’s capacity to innovate by: fostering the creation of new environments conducive to collaboration and innovation; strengthening the innovation capabilities of academia and the research sector; supporting a new generation of entrepreneurial people; stimulating the creation and the development of innovative ventures.

The nature and scale of the innovation challenges require liaising and mobilising players and resources at European scale, by fostering cross-border collaboration. There is a need to break down silos between disciplines and along value chains and nurture the establishment of a favorable environment for an effective exchange of knowledge and expertise, and for the development and attraction of entrepreneurial talents.

3.2. Areas of Intervention

3.2.1. Sustainable innovation ecosystems across Europe

The EIT will play a reinforced role in strengthening sustainable innovation ecosystems across Europe. In particular, the EIT will continue to operate primarily through its Knowledge and Innovation Communities (KICs), the large-scale European partnerships that address specific societal challenges. It will continue to strengthen innovation ecosystems around them, by

fostering the integration of research, innovation and education. Furthermore, EIT will contribute to bridge existing gaps in innovation performance across Europe by expanding its Regional Innovation Scheme (EIT RIS). The EIT will work with innovation ecosystems that exhibit high innovation potential based on strategy, thematic alignment and impact, in close synergy with Smart Specialisation Strategies and Platforms.

Broad Lines

- Reinforcing the effectiveness of the existing KICs and setting up new ones in a limited number of thematic areas;
- Accelerating regions towards excellence in countries that are modest or moderate innovators.

3.2.2. Entrepreneurial and innovation skills in a lifelong learning perspective and the entrepreneurial transformation of EU universities

The EIT education activities will be reinforced to foster innovation and entrepreneurship through better education and training. A stronger focus on human capital development will be grounded on the expansion of existing EIT KICs education programmes in the view of continuing to offer students and professionals high quality curricula based on innovation and entrepreneurship in line in particular with the EU industrial and skills strategy. This may include researchers and innovators supported by other parts of Horizon Europe, in particular MSCA. The EIT will also support the renewal of European Universities and their integration in innovation ecosystems by stimulating and increasing their entrepreneurial potential and capabilities and encouraging them to better anticipate new skills requirements.

Broad Lines

- Development of innovative curricula, taking into account the future needs of industry, and cross-cutting programmes to be offered to students, entrepreneurs and professionals across Europe and beyond where specialist and sector specific knowledge is combined with entrepreneurial and innovation oriented skills, such as digital and key enabling technologies high-tech skills;
- Strengthening and expanding the EIT label in order to improve the quality of education programmes based on partnerships between different higher education institutions, research centres and companies and offering learning-by-doing curricula and robust entrepreneurship education as well as international, inter-organisational and cross-sectorial mobility;
- Development of innovation and entrepreneurship capabilities of the higher education sector, by leveraging the EIT Community expertise in linking education, research and business;
- Reinforcing the role of the EIT Alumni community as role model for new students and strong instrument to communicate EIT impact.

3.2.3. New solutions to the market

The EIT will facilitate and empower entrepreneurs, innovators, educators, students and other innovation actors to work together in cross-disciplinary teams to generate ideas and transform them into both incremental and disruptive innovations. Activities will be characterised by an open innovation and cross-border approach, with a focus on including relevant Knowledge Triangle activities that are pertinent to making them a success (e.g. project's promoters can improve their access to: specifically qualified graduates, start-ups with innovative ideas, non-domestic firms with relevant complementary assets etc.).

Broad Lines

- Support to the development of new products and services where Knowledge Triangle actors will collaborate to make solutions market-ready;
- Provision of high-level services and support to innovative businesses, including technical assistance to fine-tuning of products or services, substantive mentoring, support to secure target customers and raise capital, in order to swiftly reach the market and speed up their growth process.

3.2.4. Synergies and value added within Horizon Europe

The EIT will step up its efforts to capitalise on synergies and complementarities with different actors and initiatives at EU and global levels and extend its network of collaborating organisations at both strategic and operational levels.

Broad Lines

- Cooperation with the EIC in streamlining the support (i.e. funding and services) offered to highly innovative ventures in both start-up and scale-up stages, in particular through KICs;
- Planning and implementation of EIT activities in order to maximise synergies and complementarities with the actions under the Global Challenges and Industrial Competitiveness Pillar;
- Engage with EU Member States at both national and regional level, establishing a structured dialogue and coordinating efforts to enable synergies with existing national initiatives, in order to identify, share and disseminate good practices and learnings;
- Provision of input to innovation policy discussions and contribution to the implementation of EU policy priorities by continuously working with all relevant European Commission services, other EU programmes and their stakeholders, and further exploring opportunities within policy implementing initiatives;
- Exploitation of synergies with other EU programmes supporting human capital development and innovation (e.g. ESF+, ERDF and Erasmus);
- Building strategic alliances with key innovation actors at EU and international level, and support to KICs to develop collaboration and linkages with key Knowledge Triangle partners from third countries, with the aim of opening new markets for KICs'-backed solutions and attract talents from abroad.

PART - STRENGTHENING THE EUROPEAN RESEARCH AREA

The EU has a history of world-class scientific and technological achievements, but its research and innovation potential fails to be fully exploited. Despite much progress in developing the European Research Area (ERA), Europe has still a fragmented research and innovation landscape, and all Member States face bottlenecks in their research and innovation systems which require policy reforms. In some areas, progress is too slow to catch-up with an increasingly dynamic research and innovation ecosystem[19].

The level of research and innovation investment in Europe is still far below the policy objective of 3% of GDP and continues to grow less than our main competitors such as US, Japan, China or South-Korea.

Meanwhile, there is a growing disparity in Europe between the innovation-leading and the innovation-lagging regions. Change is needed if Europe as a whole is to capitalise on excellence from across the continent, maximise the value of public and private investments, and their impacts on productivity, economic growth, job creation and well-being.

In addition, research and innovation are seen by some as distant and elitist without clear benefits for citizens, instilling attitudes that hamper the creation and uptake of innovative solutions, and scepticism about evidence-based public policies. This requires both better linkages between scientists, citizens and policy-makers, and more robust approaches to pooling scientific evidence itself.

The EU now needs to raise the bar on the quality and impact of its research and innovation system, requiring a revitalised European Research Area (ERA)[20], better supported by the EU's research and innovation Framework Programme. Specifically, a well-integrated yet tailored set of EU measures[21] is needed, combined with reforms and performance enhancements at national level (to which the Smart Specialisation Strategies supported under the European Regional Development Fund can contribute) and, in turn, institutional changes within research funding and performing organisations, including universities. By combining efforts at EU level, synergies can be exploited and the necessary scale can be found to make support to national policy reforms more efficient and impactful.

The activities supported under this part addresses ERA policy priorities, while generally underpinning all parts of Horizon Europe. Activities may also be established to foster brain circulation across ERA through mobility of researchers and innovators.

The goal is for an EU where knowledge and a highly skilled workforce circulate freely, research outputs are shared rapidly and efficiently, researchers benefit from attractive careers and gender equality is ensured, where Member States develop common strategic research agendas, aligning national plans, defining and implementing joint programmes, and where the

19 The ERA progress report of 2018

20 Council Conclusions on the ERA Roadmap, 19 May 2015 *[To be updated as necessary]*.

21 TFEU Article 181.2

outcomes of research and innovation are understood and trusted by informed citizens and benefit society as a whole.

This part will contribute *de facto* to all Sustainable Development Goals (SDGs), but directly to the following: SDG 4 - Quality Education; SDG 5 - Gender Equality; SDG 9 - Industry, Innovation and Infrastructure; SDG 17 - Partnership for the Goals.

1. SHARING EXCELLENCE[22]

Reducing disparities in research and innovation performance by sharing knowledge and expertise across the EU will help countries and regions that are lagging behind in terms of research and innovation performance, including the EU outermost regions, to attain a competitive position in the global value chains. Activities may also be established to foster brain circulation right across ERA and better exploitation of existing (and possibly jointly managed EU programmes) research infrastructures in the targeted countries through mobility of researchers and innovators.

Further action is therefore needed to counter the trend for closed collaborations, which can exclude large number of promising institutions, and to exploit the potential of the EU's talent pool by maximising and sharing the benefits of research and innovation across the EU.

Broad Lines

- Teaming, to create new centres of excellence or upgrade existing ones in eligible countries, building on partnerships between leading scientific institutions and partner institutions;
- Twinning, to significantly strengthen a university or research organisation from an eligible country in a defined field, by linking it with internationally-leading research institutions from other Member States or Associated Countries.
- ERA Chairs, to support universities or research organisations attract and maintain high quality human resources under the direction of an outstanding researcher and research manager (the 'ERA Chair holder'), and to implement structural changes to achieve excellence on a sustainable basis.
- European Cooperation in Science and Technology (COST), involving ambitious conditions regarding the inclusion of eligible countries, and other measures to provide scientific networking, capacity building and career development support to researchers from these target countries. 80% of the total budget of COST will be devoted to actions fully aligned with the objectives of this intervention area.

The above mentioned funding lines will facilitate specific research elements customised to the particular needs of the actions.

This intervention area will support the Horizon Europe specific objectives: Spread and connect excellence across the EU; Reinforce the creation of high quality knowledge; Increase cross-sectorial, cross-disciplinary cross-border cooperation.

[22] A criterion based on research and innovation excellence will be used to define those Member States and Associated Countries where legal entities need to be established in order to be eligible to submit proposals as coordinators under 'sharing excellence'. This criterion will address the dimensions of the overall economic performance (GDP), research performance and innovation performance in a combined manner normalised to the size of the related countries. The countries identified with this criterion are called 'eligible countries' in the context of 'sharing excellence'. On the basis of Article 349 TFEU, legal entities from Outermost Regions will be also fully eligible as coordinators under 'sharing excellence'.

2. REFORMING AND ENHANCING THE EU RESEARCH AND INNOVATION SYSTEM

Policy reforms at national level will be mutually reinforced through the development of EU-level policy initiatives, research, networking, partnering, coordination, data collection and monitoring and evaluation.

Broad Lines

- Strengthening the evidence base for research and innovation policy, for a better understanding of the different dimensions and components of national research and innovation systems, including drivers, impacts, associated polices;
- Foresight activities, to anticipate emerging needs, in coordination and co-design with national agencies and future-oriented stakeholders, in a participative manner, building on advances in forecasting methodology, making outcomes more policy relevant, while exploiting synergies across and beyond the programme;
- Accelerating the transition towards open science, by monitoring, analysing and supporting the development and uptake of open science policies and practices[23] at the level of Member States, regions, institutions and researchers, in a way that maximises synergies and coherence at EU level;
- Support to national research and innovation policy reform, including though a strengthened set of services of the Policy Support Facility (PSF)[24] (i.e. peer reviews, specific support activities, mutual learning exercises and the knowledge centre) to Member States and Associated Countries, operating in synergy with the European Regional Devleopment Fund, the Structural Reform Support Service (SRSS) and the Reform Delivery Tool;
- Providing researchers with attractive career environments, skills and competences needed in the modern knowledge economy[25]. Linking the ERA and the European Higher Education Area by supporting the modernisation of universities and other research and innovation organisations, through recognition and reward mechanisms to spur actions at national level, as well as incentives promoting the adoption of open science practices, entrepreneurship (and links to innovation ecosystems), trans-disciplinarity, citizen engagement, international and inter-sectoral mobility, gender equality plans and comprehensive approaches to institutional changes. In that context, also complementing the Erasmus programme support for the European Universities

[23] The policies and practices to be addressed range from sharing research outputs as early and widely as possible through commonly agreed formats and a shared infrastructure (e.g. the European Open Science Cloud), citizen science, and developing and using new, broader approaches and indicators for evaluating research and rewarding researchers.

[24] The Policy Support Facility (PSF), launched under Horizon 2020. The PSF works on a demand-driven basis and it offers, on a voluntary basis, high level expertise and tailor-made advice to national public authorities. Through its services, it has already been instrumental in provoking policy change in countries such as Poland, Bulgaria, Moldova or Ukraine and in bringing forward policy changes, driven by exchanges of good practice, in areas such as R&D tax incentives, open science, performance-based funding of public research organisations and the inter-operability of national research and innovation programmes.

[25] Including notably the European Charter for researchers, the code of conduct for the recruitment of researchers, EURAXESS and RESAVER Pension Fund.

initiative, in particular its research dimension, as part of developing new joint and integrated long term and sustainable strategies on education, research and innovation based on trans-disciplinary and cross-sectoral approaches to make the knowledge triangle a reality, providing impetus to economic growth.

– Citizen science, supporting all types of formal, non-formal and informal science education, including engagement of citizens in the co-design of research and innovation agenda settings and policy, in the co-creation of scientific content and innovation through transdisciplinary activities;

– Supporting gender equality in scientific careers and in decision making, as well as the integration of the gender dimension in research and innovation content;

– Ethics and integrity, to further develop a coherent EU framework in adherence with the highest ethics standards and the European Code of Conduct for Research Integrity;

– Supporting international cooperation, through bilateral, multilateral and bi-regional policy dialogues with third countries, regions and international fora will facilitate mutual learning and priority setting, promote reciprocal access and monitor impact of cooperation;

– Scientific input to other policies, through the creation and maintenance of structures and processes to ensure that EU policy-making is based on the best available scientific evidence and high-level scientific advice;

– EU research and innovation programme implementation, including the collection and analysis of evidence for the monitoring, evaluation, design and impact assessment of the Framework Programmes; strengthening dedicated support structures and facilitating trans-national cooperation among them (e.g. building on activities of National Contact Points in previous Framework Programmes); dissemination and exploitation of research and innovation results, data and knowledge, including through dedicated support to beneficiaries; fostering synergies with other EU programmes; targeted communication activities to raise the awareness of the broader impact and relevance of EU funded research and innovation.

ANNEX II

Programme Committee configurations

List of configurations of the Programme Committee in accordance with Article 12(2):

1. Strategic configuration: Strategic overview of the implementation of the whole programme, coherence across the different parts of the programme, missions and Strengthening the European Research Area
2. European Research Council (ERC) and Marie Skłodowska-Curie Actions (MSCA)
3. Research Infrastructures
4. Health
5. Inclusive and Secure Society
6. Digital and Industry
7. Climate, Energy and Mobility
8. Food and Natural Resources
9. The European Innovation Council (EIC) and European Innovation ecosystems

ANNEX III

Information to be provided by the Commission in accordance with Article 12(6)

1. Information on individual projects, enabling the monitoring of the entire lifetime of each proposal, covering in particular:

— submitted proposals,

— evaluation results for each proposal,

— grant agreements,

— completed projects.

2. Information on the outcome of each call and project implementation, covering in particular:

— results of each call,

— outcome of negotiations on grant agreements,

— project implementation, including payment data and outcome of projects.

3. Information on programme implementation as well as the synergies with other relevant Union programmes.

4. Information on the execution of the Horizon Europe budget, including information on commitments and payments for initiatives under Articles 185 and 187 TFEU.