ANNEX 4 - HORIZON EUROPE CLUSTER 4

DIGITAL, INDUSTRY AND SPACE

1. Global Challenges and Their Drivers

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

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

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

Key facts and figures:

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

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

chain has shrunk gradually over the past 20 years.[64] Most recently (2017-18), EU companies reduced their global R&D share in ICT industries by more than 8%.[65]

- ➔ Space technologies, data and services have become indispensable in the daily lives of European citizens: when using mobile phones and car navigation systems, watching satellite TV, enhancing weather forecast and improving emergency services. The value generated from **space related activities** is estimated between EUR 46 to 54 billion representing a share of 21% of the worldwide business. In addition, the capacity to access and use space is a strategic asset for Europe and its Member States, which impacts many other sectors,[66] and opens up many business opportunities for early-stage and high-tech companies, especially in combination with digital technologies and other sources of data. The EU must make the most of these opportunities by fully developping and exploiting the potential of European Space Programmesand its components Copernicus, EGNOS and Galileo, SSA and GOVSATCOM.

- ➔ Research and Innovation are recognised as an important source of economic growth and competitiveness, but there is an **urgent need for more investments** in Europe, in particular in industry. Industry accounts for 64% of private sector R&D expenditure and for 49% of innovation expenditure.[67] The R&D conducted within the business enterprise sector in the EU was equivalent to 1.36 % of the EU-28 GDP in 2017, significantly below the EU's 2% target for the private sector and lower than in South Korea (3.27%), Japan (2.57%), Switzerland (2.39%) and the United States (1.97%).[68] In digital for example R&D intensity is about 5% as opposed to 12% in the US and 11% in Japan.[69]

- ➔ The EU shows higher shares of R&D in medium-tech sectors (circa 40%) as compared to USA and China (circa 20 and 30%), while lower shares of R&D in high-tech sectors are seen with respect to USA and China (circa 75 and 43%). There is a need to integrate horizontal industrial and innovation policies with sector/technology specific ones, to promote the industrial transformation towards the knowledge economy by reinforcing the presence of high-tech sectors, while fostering the modernisation of low- and medium-tech sectors and their capacity to absorb new technologies.

- ➔ EU public investment in R&D in digital technologies is 40% less than in the US; and in critical areas, such as Artificial Intelligence (AI), public and private investments in

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

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

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

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

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

[69] 2012 PREDICT REPORT http://is.jrc.ec.europa.eu/pages/ISG/documents/OnlineversionFINALPredict2012withnumbersv2.pdf

the EU are 4 times less than in the US. China set up a strategy plan[70] to support an AI industry worth 150 b$ including the development of AI chips. This complements the 2025 plan, which strives to secure its position as a global powerhouse in high-tech industries, and focuses heavily on intelligent manufacturing in 10 strategic sectors. The strategy seeks to raise the domestic content of core components and materials to 40% by 2020 and 70% by 2025.[71] In Space, the EU governments' investments of EUR 8.2 billion in upstream space programmes are well under half of the NASA budget, and probably under one third of the total US space budget.

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

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

An accelarating global resource consumption has increased environmental pressures beyond sustainable levels. As a major user of natural resources, industry needs to reduce its carbon and materials footprint in order to ensure sustainability in the circular economy and to reach Paris Agreement targets. New technologies should notably reduce energy consumption and be part of a circular economy value chain which will contribute to Europe's competitiveness in a context of increased sustainability standards.

<u>Key facts and figures</u>:

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

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[70] New Generation of Artificial Intelligence Development Plan

[71] Made in China (MIC) 2025

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

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

[74] European Environment Agency database.

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

investments in deep decarbonisation technologies are needed. These investments are estimated to be around an additional EUR 5.5 billion per year for the above mentioned sectors, an 88% increase compared to the baseline scenario.[76]

- ➔ The rapid expansion of the digital sector has environmental consequences, including considerable increases in the extraction of critical raw materials, in energy consumption (e.g. from digital infrastructure and other auxiliary equipment), as well as in Green House Gas emissions (4% of global annual increase[77]).

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

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

Key facts and figures:

- ➔ There are substantial variations in the level of economic activity and labour market performance across Europe, including in their technological specialisation and R&D investment. Long-term economic and industrial decline, low levels of education and a lack of local employment opportunities emerge as key drivers of the anti-EU vote.[78]
- ➔ Evidence indicates a considerable accumulation of wealth by a small segment of society, as others face increasing hardship and a widening inequality gap. The Commission's Ethics Group warns that new forms of work bring unparalleled flexibility but also precariousness; and exposes the limitations of existing social models to guarantee decent livelihoods for many Europeans.[79]
- ➔ Due to the deployment of new technologies and automation, there is an increase in the number of high-skilled jobs. However, around 20% of European workers judged their current ICT skills insufficient. The highest skill mismatches are in occupations related to ICT, manufacturing and construction. A third of the EU labour force has an insufficient level in digital skills.[80] The lack of skilled individuals and talents risks slowing down investments. For instance, 9 out of 10 manufacturers are struggling to find the skilled workers they need. Similarly, more than half of companies looking for ICT specialists report difficulties in recruiting them. Hence, there is a need to reform the current educational system, and better anticipate and develop skills to equip the labour force with appropriate skillsets.

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

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

[78] The Geography of EU Discontent

[79] Future of Work, Future of Society - European Group of Ethics in Science and New Technologies, December 2018

[80] Digital Economy and Society Index, https://ec.europa.eu/digital-single-market/en/desi

- ➔ New technologies such as digitisation and automation will reshape economies and societies in all the regions and will have differentiated impacts across the regions and also across the regions within one nation in Europe and globally.[81]

2. EU Policy Objectives

Against this background, the overarching vision behind the proposed investments is **a European industry with global leadership in key areas, fully respecting planetary boundaries, and resonant with societal needs** – in line with the renewed EU Industrial Policy Strategy.[82] Three objectives will be pursued across the cluster, in synergy with other EU instruments and initiatives:

(i) Ensuring the **competitive edge and autonomy of EU industry**.
Key enabling technologies, including digital ones, and new services offered by digital and space technologies, will help revolutionise both industry and society and reinforce Europe's global industrial leadership. Developing and mastering these technologies will give EU industries the competitive edge they need for leadership in global markets; and promise innovation and market breakthroughs to achieve a circular, resource efficient and climate-neutral EU economy.

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

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

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

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

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

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[81] OECD Regional Outlook 2019 - Leveraging Megatrends for Cities and Rural Areas, http://www.oecd.org/regional/oecd-regional-outlook-2019-9789264312838-en.htm

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

The breakthrough technologies and solutions to be developed in this cluster[83] will, in conjunction with new business models, contribute to bring about climate-neutral EU industries by 2050, thereby delivering on the 2050 Long-term strategy, calling for a climate-neutral Europe by 2050;[84] and foster a circular economy.[85] Future factories will be climate-neutral, resource-efficient and fully integrated in the circular economy. The climate-neutral and circularity ambitions will reinforce one another.

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

(iii) A **major contribution to inclusiveness**: From the outset we must involve and empower workers, consumers and firms to make sure that they have access to, and take up, these technologies (reflecting gender and other diversity issues where appropriate). *In conjunction with other programmes and initiatives*, there must be adequate support for the development of skills and the development of regions, cities and rural areas – ensuring a socially fair transition not leaving anyone behind. We must also pay due regard to safety, and to the impact of technologies and industrial transformation on people and societies.
The EU technology developments will follow a **human-centred approach**, going hand in hand with European social and ethical values, social inclusiveness, and the creation of sustainable, high-quality jobs including through social innovation. For example in Artificial Intelligence developments will follow the key requirements[86] for trustworthy AI identified by the High-Level Experts Group established by the Commission.

The interaction of science, technology, social sciences and humanities will be important in this respect, as will be the input of creative sectors and artists to sustainable inclusive innovation and to human-oriented technologies.[87]

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

3. Targeted impacts

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

In key strategic value chains,[88] European players will be present to secure EU non dependence / autonomy and secure leadership in key enabling technologies

[83] including low-power processors and computing architectures
[84] A Clean Planet for all – A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, COM(2018)773
[85] Closing the loop - An EU action plan for the Circular Economy, COM(2015)614
[86] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Building Trust in Human Centric Artificial Intelligence (COM(2019)168)
[87] www.STARTS.eu
[88] https://ec.europa.eu/growth/content/stronger-and-more-competitive-eu-industry-president-juncker-open-2019-eu-industry-days_en

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

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

4. Key R&I Orientations

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

The cluster will emphasise **international cooperation** in areas of common interest, in pursuit of a level playing field, reciprocity and common standards; and also highlight Europe's strong position in sustainability.

I. Enabling technologies ensuring European leadership and autonomy

4.1 Manufacturing Technologies

Innovative manufacturing technologies will contribute to sustainable prosperity for all and reinforced strategic advantages in terms of increased productivity, enhanced job quality and reduced carbon footprint. Priorities include:

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

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

4.2 Key Digital Technologies

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

At the heart of digital transformation is the continuous progress in the key underlying electronics and photonics components and systems, software technologies and connectivity platforms. Further scaling in mainstream nanoelectronics raises physical and economic challenges, but progress in digital components and devices continues through disruptive innovations, thanks to new materials (such as graphene), low-power electronics and alternative processing concepts, like neuromorphic, that map cognitive processes into electronic circuits, and quantum information processing. These innovative approaches unfold a new era of digital applications providing unprecedented levels of computing power, trust and security, as well as high precision sensing and low energy consumption.

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

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

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

4.3 Advanced Materials

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

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

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

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

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

4.4 Emerging Enabling Technologies

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

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

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

Examples include:

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

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

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

4.5 Artificial Intelligence and Robotics

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

Amid fierce global competition, a collective and decisive EU Research and innovation agenda for AI will be instrumental in bringing its benefits to all our citizens and businesses whilst ensuring high ethical standards.[89] The EU must also promote the adoption of principles and global standards which will ensure an ethical approach to the development and use of technologies at both EU and international level.

Citizens will experience the advantages of AI in daily life, such as traffic optimization and autonomous driving to reduce citizens everyday stress and drastically reduce the number of road accidents, to truly intuitive AI-based systems adapting to human needs, to support them in specific tasks, improving their working conditions, and making the technology easy to use by all, even the non-experts in AI. Also the society as a whole will benefit from AI-based solutions to optimise the lifecycle of resources (energy, food, etc.), and make it more environmentally and economically sustainable, from production to distribution and use. Medical doctors will ask the support of powerful data-intensive machine learning to support their diagnostic and therapy decisions. Firefighters will get the support of robots to approach hazardous intervention zones.

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

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

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

4.6 Next Generation Internet

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

The Internet of today has significant limitations. The risk of breaches of security or privacy, lack of accessibility, lack of user control of their data, and manipulation or disinformation are some of the major challenges to be tackled.

Furthermore, the internet economy is vulnerable to concentration of market positions from devices to networks. Concentration in few powerful providers generate potential threats of user lock-in. Breaches of citizen's security or privacy, lack of accessibility, lack of user control of their data, and manipulation or disinformation are some of the major challenges to be tackled.

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

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

The next generation Internet (NGI) initiative aims to develop the key technology building blocks and the infrastructures for the Internet of tomorrow, while addressing the growing societal and political concerns and service needs, with a human-centric trustworthy internet enabling full connectivity and accessibility and collective intelligence (people, processes, data, content and things) and safeguarding core European values. It aims at supporting an autonomous European Internet supply chain, which can meet the future industrial and societal needs establishing Smart Networks and Services (including Internet of Things, cloud/edge computing continuum, and cognitive cloud) and Content platforms. The initiative addresses the innovative immersive, media and business applications supported by such platforms. It builds on a comprehensive strategy including a technology push and an application/ market/ end-user pull, and composed of technological layers with different time to market cycles.

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

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

4.7 Advanced Computing and Big Data

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

As transistor-based computers are reaching physical limits, the next generation of computing capabilities will be developed based on disruptive concepts, technologies and paradigms, keeping in mind environmental standards (e.g. ‘Green ICT’).

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

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

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

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

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

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

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

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

4.8 A globally competitive space sector reinforcing EU autonomy

R&I actions will foster the competitiveness of space systems in particular for ultra-high throughput telecommunication, support the integration of satellites in 5G networks and high-resolution earth observation. Digital and automated industrial processes will enable seamless manufacturing for the production of cost effective space systems including constellations. In the mid to long term, the future space ecosystem should include hybrid, smart and reconfigurable satellites, which can be assembled and serviced directly on-orbit, with a de-orbiting capacity.

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

EU-funded research will also contribute to critical technologies, space science and missions and outreach and education activities. Synergies with non-space sectors will be promoted as well as downstream exploitation.

These investments should lead to globally flexible, reconfigurable and competitive space assets and services, which can be tailored to evolving customer needs. This will provide the EU space sector with a global competitive edge, enhance its autonomy, contribute to the EU Space Strategy as well as to societal challenges. These objectives will be pursued jointly with the European Space Agency and national space programmes in Europe in a mutually supportive and coherent approach.

II. Accelerating economic and societal transitions

4.9 Circular Industries

In a circular economy, the value of products, materials and resources is maintained for as long as possible and waste is minimised. The EU Circular Economy Action Plan[90] includes a wide range of initiatives for a sustainable, low-carbon, resource efficient and competitive economy. It also relies on research and innovation through the entire life-cycle to prevent new and larger waste streams and to tackle scarcity of resources, and price volatility. Also needed are solutions to increase material efficiency and recover the economic value of waste streams, while radically decreasing their environmental footprint. Priorities include:

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

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

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

4.10 Low-carbon and Clean Industries

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

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

The required technologies include process and heat electrification, switch to decarbonised energy and feedstock, CO2 capture and usage, catalysis and artificial photosynthesis, waste heat recovery, and materials for re-use and recycling, all of which need to be developed and

[90] COM(2015)0614

demonstrated in industrially relevant or operational environments before the first market deployment in the EU.

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

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

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

a. New services from Space for the EU society and economy

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

Innovative applications will be developed for European and global uptake for the **European Union** Earth Observation System (Copernicus), in areas such as, for example, climate mitigation, monitoring GHG, environment, including Polar Regions, urban planning, security, etc. These will rely on innovative and evolutive data and information infrastructures and services.

Further developments in sensors technologies and data processing will be supported as well as new services for Space Surveillance and Tracking (SST) and research on space traffic management, space weather and near Earth objects necessary to ensure the security of critical infrastructure both in space and on Earth for **Space Situational Awareness (SSA)**.

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

These investments will provide EU citizens with more accurate mobility services, higher resolution earth observations for climate and environment as well as more efficient and new emergency and security services.

5. European Partnerships

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

Partnerships[91] have proven instrumental. They would be more effective compared to ordinary calls because they would ensure industries working together across sectors and value chains, based on predefined targets. This is a pre-requisite for achieving, for instance, circular economy goals, where cross-sectoral cooperation along and across value-chain cooperation is vital. The following areas for future partnerships with a lead under this cluster have been identified:

- Made in Europe
- Key Digital Technologies (institutional)
- Photonics
- Artificial Intelligence, data and robotics
- Smart networks and Services (institutional)
- HPC (institutional)
- Circular and Climate-neutral industries
- Clean Steel
- Metrology (institutional)
- Global Competitive Space Systems

6. Missions

One of the main novelties of Horizon Europe is the introduction of missions; high-ambition, high-profile initiatives which will put forward concrete solutions to challenges facing European citizens and societies. Missions are currently in the process of being defined within five areas;

- adaptation to climate change including societal transformation
- cancer
- healthy oceans, seas, coastal and inland waters
- climate-neutral and smart cities
- soil health and food

Accomplishing missions will require a cross-cutting approach, drawing on research and innovation activities defined not only through individual Clusters, but across Horizon Europe and beyond. Research and innovation activities within this Cluster thus have the potential to support missions in all of the above-mentioned areas. The synergies between each mission and cluster will be further explored as possible missions take shape.

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