MADE IN EUROPE

The manufacturing partnership in Horizon Europe - Strategic Research and Innovation Agenda (SRIA)

Version October 2021

European Commission

EFFRA
EUROPEAN FACTORIES OF THE FUTURE RESEARCH ASSOCIATION

Made in Europe

The manufacturing partnership in Horizon Europe (2021 – 2027)

1 The Made in Europe approach to overcome current challenges and exploit opportunities

1.1 Summary

European manufacturing is at the centre of a twin ecological and digital transition, being both driver and subject to these changes. At the same time, manufacturing companies must maintain technological leadership and stay competitive. The size and the complexity of the associated challenges - such as the integration of Artificial Intelligence, the use of industrial data, the transformation into a circular economy and the need for agility and responsiveness - requires pooling of resources and a novel approach of cooperation.

The Made in Europe Partnership will be the leading European lighthouse and driver of this change, bringing together the leading actors from manufacturing and relevant European industrial ecosystems, coming from academia, industry, non-governmental organisations and the public sector. The Partnership will serve as a platform for national and regional manufacturing technology initiatives and the required disciplines and technologies, creating economies of scale, common understanding and alignment of objectives and priorities. Strategic cooperation with key actors at national, regional and local levels will be developed, to ensure urgently required exploitation and implementation of research results.

Based on joined expertise and resources, the Made in Europe partnership will be the voice engine for sustainable manufacturing in Europe. It will boost European manufacturing ecosystems towards global leadership in technology, towards circular industries and flexibility. The Partnership will contribute to a competitive, green, digital, resilient and human-centric manufacturing industry in Europe.

1.2 Where does European manufacturing stand today?

1.2.1 International competition and high expectations in terms of reducing the environmental impact

Europe is home to a competitive, wealth-generating manufacturing industry and of extremely comprehensive manufacturing ecosystems which accommodates complete manufacturing supply chains. Europe's manufacturing industry is the **backbone of the European economy**, bringing prosperity and employment to citizens in all regions of Europe.

The EU is a global market leader for high-quality products, and European Industry is the **world's biggest exporter** of manufactured goods. Manufactured goods represent 83% of EU exports. Thanks to the strengths of its manufacturing industry, the EU annually achieves a considerable trade surplus in the trade of manufacturing goods, which accounts for 286 billion euro in 2018[1]. This healthy surplus generated by the manufacturing industry allows the EU to finance the purchase of other, non-manufactured goods and services, such as raw materials, energy (oil and gas), and services. The surplus in manufactured goods thus compensates the deficits which are generated by purchasing non-manufactured goods. However, the surplus generated by EU's manufacturing sector cannot fully compensate these deficits anymore: the overall EU trade balance (counting both manufactured goods and non-manufactured goods) changed from a surplus of 22 billion EUR in 2017 to a deficit of 25 billion EUR in 2018. From a

[1] Eurostat.

macro-economic perspective, this is not a healthy situation in the long run, and shows the importance of a strong manufacturing industry.

Although Europe’s industry is a world-wide technology leader in most manufacturing market segments, this position is constantly being challenged by **international competitors**. While being highly competitive, statistics show that the EU manufacturing industry constantly needs to keep up with international competition. Competitors, especially from Asian economies, have reached advanced levels, often supported by state-supported programmes. Furthermore, industrial structures are changing with significant foreign investments, including those by emerging economies, in Europe and in the US. And finally, such as large scale digitalisation, changes in trade rules, and global environmental concerns create new challenges.

European industry is also driving the **transformation to climate neutrality and sustainable circular economy**. While faced with increasing international competition, European manufacturing companies are at the same time in the process of constantly becoming “more productive with less”, both in terms of material usage and energy consumption. The manufacturing industry is in a key position to enable the transformation to truly circular business models and the production of new environmentally friendly products in existing or emerging value chains. For ‘true’ circularity and zero-waste much has to be done, as illustrated by the graph below. Although the process has started, the speed of change needs to increase. The need to achieve circularity and minimal environmental impact implies radical innovations in manufacturing and related value chains to produce future green products.

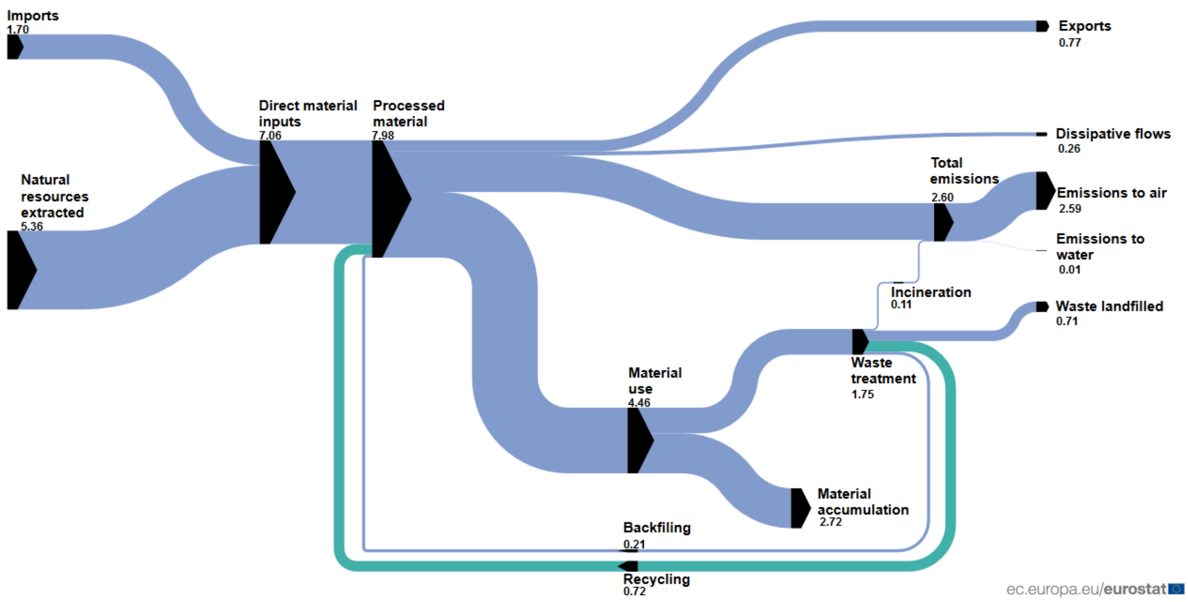

Figure 1: material flows true scale in Gt/year (billion tonnes per year) in 2017, EU27 Source: Eurostat;

1.2.2 Today’s challenges and opportunities for Europe’s manufacturing industry

Despite competitive pressures on a world-wide level, Europe can still be seen as the technology and sustainability leader in many areas. European companies have been successfully operating in global markets and are champions in a wide range of sectors. At the same time, their environmental impact is usually smaller when compared to non-European companies.

Nevertheless, the European manufacturing industry is currently going through an exceptional transformation process that is driven by several factors:

1. European society demands **minimal environmental impact** of industry. European industrial companies need to re-evaluate their resource efficiency and the carbon intensity of their entire supply chains. Changes of policy frameworks, markets and customer preferences induce structural changes in manufacturing value chains, for example the move to electro-mobility in the case of the automotive sector. On the other hand, increasing environmental consciousness is an opportunity for European-made environmental-friendly but high-priced products.

2. In addition, **Circular Economy models** and next-generation **sustainable materials and products** induce profound changes in manufacturing systems and their supply chains. This requires life-cycle thinking from product design and production, via use, to recycling and remanufacturing.

3. The current COVID-19 crisis manifested the **vulnerability of industries** and the **unpredictability of external shocks**. Such unpredicted external shocks can have many causes: be it a pandemic like COVID-19, a tsunami and nuclear accident (Fukushima 2011), a financial crisis, a possible trade war or any other event which cannot be known in advance. These events once more show that the European manufacturing industry needs to become **resilient and agile**. It showcases the importance of possessing **flexible and reconfigurable production lines** within a country or region.

4. The COVID-19 crisis also demonstrated the dependence of European Industry on global sourcing. European industry needs to **regain or at least maintain manufacturing sovereignty** and sustain technological leadership in key areas. Improving the level of sovereignty **in key areas** and **critical value chains** takes time and calls for a coordinated European effort on manufacturing.

5. **Digitalisation and new technologies** offer immense opportunities which accelerate innovation and industrial transformation. Digitalisation is changing value chains, increasing the overall efficiency of manufacturing. Digital technologies need to be developed to fit industrial conditions.

6. The **data economy** will affect how to do business, create value, and connect to customers. Opportunities for growth will emerge for companies understanding the data economy and digital transformation also from the non-technological (i.e. business, human, legal, ethical) point of view. This process is still at the beginning; for instance, European companies have not yet embraced the potential of monetising the data they possess and work with it.

7. Nevertheless, at the same time, digitalisation also involves some threats which need to be mitigated: the more digital manufacturing companies become, the more vulnerable they are in terms of **cyber-security**.

8. **New business models** are emerging or are further developed. Suppliers of manufacturing solutions are increasingly becoming service companies, data and software companies, or they establish alliances with data companies and disruptive start-ups. Concepts, such as ”manufacturing-as-a-service” and “collaborative product-service engineering” are taking shape.

9. The fast-moving transition towards smart autonomous systems and the increased use of Artificial Intelligence, Machine Learning and collaborative robots is changing the **interactions between humans and technology**. The European society – citizens, consumers and workers – is in the process of adopting and accepting these key technologies which are needed for industrial competitiveness.

10. Companies are concerned about shortages of **skilled personnel**, also considering an ageing workforce. In particular, for SMEs, the shortages of qualified staff and talents have become a major barrier and threat.

11. **International competition** is high, especially from Asia. In Asia and America, big public-private manufacturing partnerships are being launched (such as Made in China).

12. With the majority of the EU’s population living in urban areas, environmentally friendly and low-emission production is more important than ever in order to fulfil local acceptance, regulations, etc. While manufacturing companies are locating or re-locating, **societal challenges** need to be considered simultaneously.

All these developments put Europe’s manufacturing industry in a challenging position. While still competitive and at the forefront of technology, there is a risk that Europe loses its manufacturing leadership position to Asia and America if technology investments are not synchronised. In particular, the situation is challenging when considering the data and data platforms that are crucial for manufacturing competitiveness. Europe needs to accelerate innovation and investments as well as effectively roll out and adapt the resulting innovations over the many manufacturing companies in Europe.

1.2.3 Compared to the past, there is a need for a more ambitious and better-coordinated approach

In Europe, most of the research and innovation efforts are being done by European Industry; some 70% of Europe’s research investments are performed by Europe’s engineering and manufacturing companies. Pre-competitive collaborative research has a long tradition in Europe: companies operate within regional innovation and industrial ecosystems, often with world-class companies in the lead, and with many other companies (often SMEs) and research institutes being involved. Moreover, national and regional public initiatives provide support to these ecosystems, for example advanced manufacturing, smart manufacturing, or fourth-industrial-revolution initiatives in Member States. Cooperation between initiatives has been facilitated by the ManuFuture ETP, EFFRA and the Factories of the Future PPP. These initiatives have helped to gain new insights and innovations, which have been shared between Europe’s regions.

Given the vast challenges which are described above, public and private actors need to reinforce cooperation to help Europe's manufacturing industry to overcome these challenges and embrace new opportunities. An **ambitious European partnership in manufacturing** is therefore needed to:

- pool resources from scattered regional, national, and European manufacturing initiatives to support European manufacturing industry so that it can compete with competitors supported by vast investments done outside Europe;
- boost digital transformation and data-based business in manufacturing industries;
- speed up the transition to green and resource-efficient manufacturing value chains;
- roll out the developed technologies to companies, especially SMEs, in all regions of Europe;
- support the workforce in continuous learning and technology adoption.

The new Made in Europe roadmap is distinct from previous roadmaps by the Factories of the Future partnership. It is clearly targeted on the twin ecological and digital transitions. It is more ambitious in terms of technologies, sustainability and business approaches, and it aims at embracing additional opportunities arising from global trends, environmental needs, and changing consumer preferences.

Regarding the scope and sectors covered, the proposed Made in Europe Partnership will include activities to advance logistics and packaging, bottling and sorting, waste processing and sophisticated structures for the construction industry, which were are not in the focus of the Horizon 2020 PPP Factories of the Future.

The Made in Europe Partnership – planned to be jointly implemented by the European Commission (DG RTD, DG Connect), member states and by EFFRA – becomes the centrepiece, which brings together companies, RTOs, academia, societal actors, and national/regional manufacturing initiatives. Particular attention is paid to smaller companies that need to be included in the transition to sustainable and digital. This comprehensive approach will bring together the amount and diversity of expertise, knowledge, and assets that single companies, single regional ecosystems, or even single national initiatives alone cannot achieve.

The European Partnership will address the entire manufacturing value chain in Europe and concentrate on spreading manufacturing excellence among companies, especially SMEs and including product design, engineering and manufacturing start-ups and scale-ups. The partnership will guarantee the competitiveness, sustainability and sovereignty of Europe's manufacturing industry, defend Europe's technology leadership in the world as well as the prosperity and well-being of employees, consumers, and society.

The Partnership will contribute strongly to the interaction among key players that steer and/or implement national and regional manufacturing innovation initiatives. New actors will be involved and listened to, such as local authorities in charge of attracting industry to cities and communalities.

1.3 The Made in Europe vision and objectives

1.3.1 Vision for 2030

Europe's manufacturing industries' vision for 2030 is to **reinforce its global position in terms of competitiveness, productivity, and technology leadership**[2]. The goal is to increase the **number and attractiveness of jobs**, while at the same time securing the **environmental, economic and social sustainability** for future generations in Europe. While global competition is increasingly challenging, Europe will reinforce its position because of its **technological leadership** and capacity to handle complexity and to fully embrace **digital technologies** which in return provide the basis to increasing services around manufacturing and along the product lifecycle.

Europe will specialise in the engineering of complex and highly interconnected value creation processes and systems. Its experience, creativity and unique tradition and identity will support the consolidation of European manufacturing. In 2030, the European manufacturing industry will be delivering **excellent solutions**, ensuring individual user-satisfaction (including customised products and services), high quality and environmental and social sustainability. Europe will be the leader in manufacture engineering for **highly personalised and complex products and services** in a broad range of sectors, including aeronautics, automotive, production equipment, renewable energies, space and defence, and customer goods.

In 2030, Europe will be at the forefront of **resource efficiency and circular economy** implementation, which will contribute to its competitiveness at the global level and support its environmental sustainability. Manufacturing systems in Europe will be flexible and resilient, with optimal balance and integration between humans and machines. The European workforce will develop new skills to be prepared to address these challenges.

Europe will be the **leading "solution provider"** in production technology, digitalisation, resource efficiency and circular economy implementation, which can only be achieved through the continuous development and exploitation of new technologies. Research and innovation will promote industrial digital transformation and thus enhance the competitive strengths of European companies, products, production systems, and services.

This vision focuses on **ensuring competitiveness and sustainability** , and supporting **resilient and adaptive** manufacturing ecosystems able to cope with external disturbances and rising environmental and social requirements. The transformation to a circular economy will need **innovative business models**, which will furthermore rely on the data economy.

[2] http://www.manufuture.org/wp-content/uploads/Manufuture-Vision-2030_DIGITAL.pdf

1.3.2 General objectives of the Made in Europe Partnership and supporting EU policies

The Made in Europe Partnership will take a leading role in the transition of manufacturing towards a sustainable, economically successful activity with proper consideration of the well-being of workers and society. Achieving these principles will require further digital transformation of the manufacturing industry.

Made in Europe Partnership has four General Objectives, namely:

1. ***Ensuring European Leadership & manufacturing excellence***
2. ***Achieving Circular and climate-neutral manufacturing***
3. ***Mastering the Digital transformation of manufacturing industry***
4. ***Creating Attractive added-value manufacturing jobs***

These four Partnership Objectives are related to different EU policies which address manufacturing: these are (i) the new industrial strategy for Europe, (ii) the European Green Deal, (iii) a Europe fit for the digital age and an Economy that works for people.

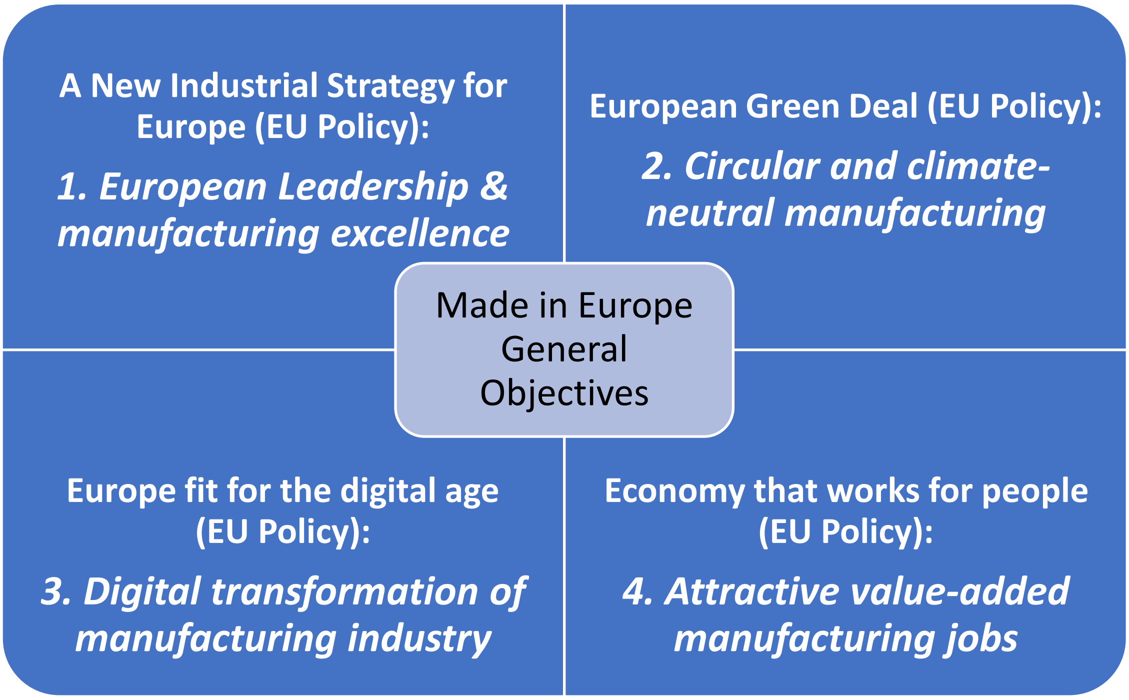

Figure 2: The four General Objectives the Made in Europe Partnership, in line with the EU's political priorities which address manufacturing industries.

1.3.3 *Specific objectives of the Made in Europe partnership*

The following four Specific Objectives drive the Made in Europe Partnership, by providing a clear focus on the generation of **impact**.

- **Specific Objective 1: Efficient, responsive and smart factories and supply chains**
- **Specific Objective 2: Circular products & Climate-neutral manufacturing**
- **Specific Objective 3: New integrated business, product-service and production approaches; new use models**
- **Specific Objective 4: Human-centred and human-driven manufacturing innovation**

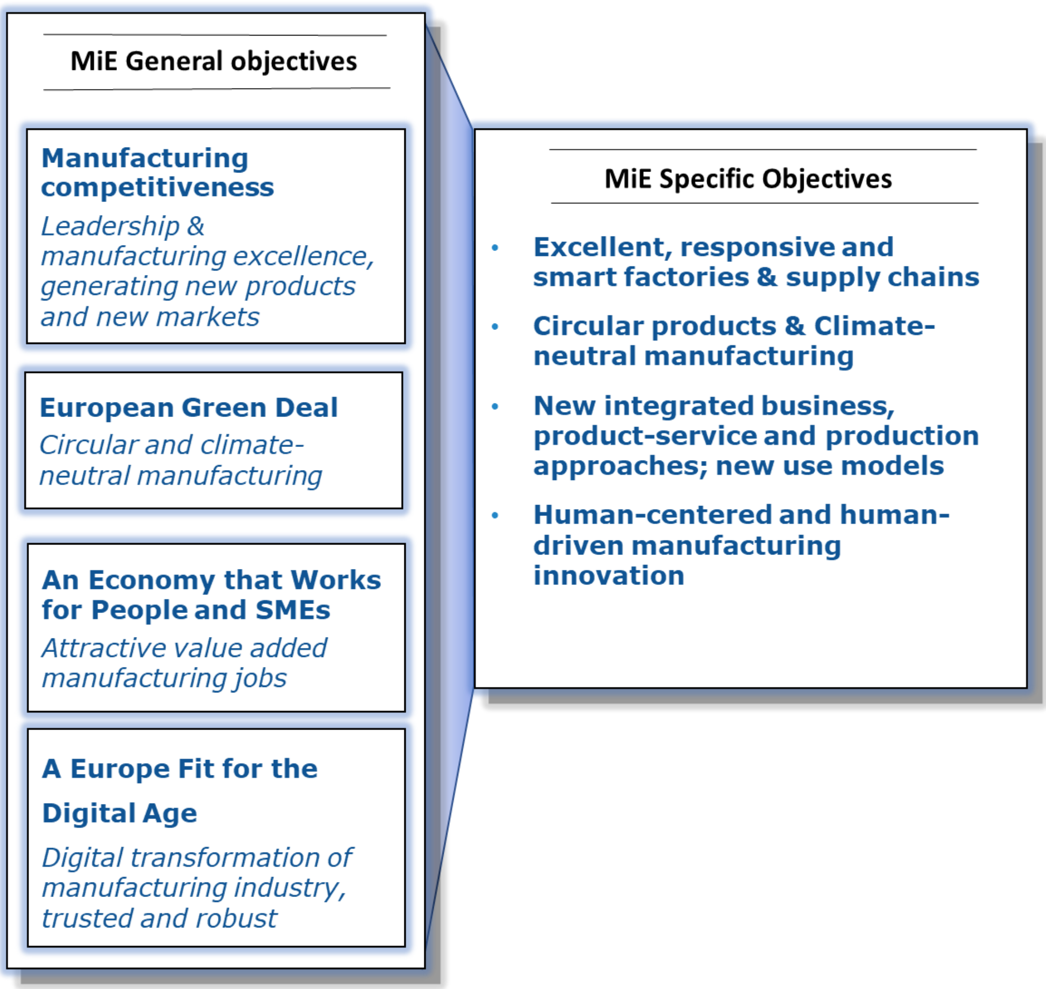

Figure 3: The Made in Europe Specific Objectives, providing a framework for the Research & Innovation Objectives and assuring the alignment with the General Objectives

In section 2 of this document, these Specific Objectives are broken down in more detailed Research and Innovation Objectives, which provide the input for the preparation of future work programmes.

1.3.3.1 Specific Objective 1: Efficient, responsive and smart factories and supply chains

Made in Europe aims to contribute to more efficient, responsive and smart factories and supply chains. Efficient and responsive production combines speed, precision, quality and reliability with flexibility and agility. Manufacturing companies need to produce from very small lot-sizes to big volumes and there is a growing need for the ability to quickly scale up from small to big lot-sizes whilst retaining the required quality in **zero-defect and first-time-right** production. Made in Europe will provide technologies and methods for zero-defect and zero-downtime high-precision manufacturing, including predictive quality and non-destructive inspection methods. It will also contribute to technologies for scalable, reconfigurable and flexible first-time-right manufacturing.

The manufacturing industry needs to respond quickly to market disruptions, changing customer demands, fluctuating characteristics of raw materials and components, and advanced emerging technologies that can be potential differentiators. Simultaneously, the manufacturing industry needs to increase quality and efficiency and reduce Total Cost of Ownership. Hence, upgradable and robust manufacturing systems and plants are necessary for **flexible, responsive and resilient manufacturing**. Here, Artificial Intelligence, advanced robotics and other digital technologies will help. Therefore, Made in Europe will drive research in AI for manufacturing that is geared towards concrete applications based on context-dependent data collection, and assurance of data quality.

Products are increasingly complex with increasing amount of electronics or micro-features and advanced (multi-)materials. Products are also becoming smarter, stronger, lighter and more miniaturised and functionally integrated whilst remaining safe and secure. Completely new solutions will be introduced when designing future **sustainable products** enabling durability, energy-saving, the replacement of scarce or hazardous materials. Manufacturing system capabilities need to follow product and material roadmaps to enable the viable and sustainable manufacturing of these high-tech products. Made in Europe will contribute with advanced manufacturing processes to a new smart and complex products and solutions. Made in Europe will enhance parallel product and manufacturing engineering and the design for end-of-life/re-use/recycling, which contributes to sustainable products, services and manufacturing networks.

Highly complex, low volume products are mostly manufactured in (regional) ecosystems with a large number of SME first- and second-tier suppliers for world-class OEMs. Such ecosystems require data spaces with standardised data formats for the exchange of design, manufacturing, logistics and other data. Made in Europe will contribute to **responsive value chains** by studying advanced data spaces to support smart factories sharing data with other organisations.

The Research & Innovation Objectives associated to Specific Objective 1 are described in section 0.

1.3.3.2 Specific Objective 2: Circular products & Climate-neutral manufacturing

Made in Europe aims at ultra-efficient, low energy, circular and carbon-neutral manufacturing. Made in Europe will exploit the possibilities offered by advanced materials, digital technologies and manufacturing technologies to achieve a considerable reduction of the ecological impact and CO2-emissions. On an ecosystem level, **recycling and re-use** of materials and components will be increased while still raising the performance of the manufactured products.

With higher expected CO2 prices and scarcity of key materials, the economics of manufacturing and materials use and re-use will change. This will have an impact on manufacturing technologies and will require **new, different manufacturing equipment**. Hence, Made in Europe will study advanced de-manufacturing, re-manufacturing and recycling technologies for a circular economy involving manufacturing with new and substitute materials.

Resource-efficient or circular approach necessitates the understanding of material flows and cooperation among organisations along the life-cycle and across sectors. This will require appropriate metrics and parameters which allow optimisation along the life-cycle. **Circular-by-design approach** needs to be applied including virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks. Moreover, digital platforms and data sharing solutions are needed to enable the management of circular product and production-systems life-cycles.

The Research & Innovation Objectives associated to Specific Objective 2 are described in section 2.2.

1.3.3.3 Specific Objective 3: New integrated business, product-service and production approaches; new use models

The service component of the revenues generated by products, in particular B2B products, continues to increase. Made in Europe will **couple** more tightly the design, manufacturing and (re-)configuration of products **with the services** that are associated to these products, considering also that these services evolve along the lifecycle of these products. In this context, product-service systems can be manufacturing systems that enable excellence and flexibility in future manufacturing, as well as high-value systems in areas such as mobility, energy, and health. Designing and engineering product-services, with growing amounts and value of software, requires interaction between many stakeholders from both the user- and supplier-side. Hence, the need for collaborative and digitalised ecosystems increases.

The increasing complexity of products, growing sustainability requirements, and the increasing innovation rate require that **product design and engineering are carried out in parallel with manufacturing system engineering and configuration**. In this context, the notion of Digital Twinning plays a role, where for each product design and each manufactured product a virtual/digital representation is maintained. Made in Europe will develop new technologies and methods for collaborative product-service engineering and manufacturing for customer-driven value networks.

In the future, efficient and smart factories can fully offer and deploy their capabilities in **dynamic and sustainable manufacturing ecosystems** where digitalisation delivers new ways to interact with customers, consumers, and users. Made in Europe will contribute to making this a reality, and will define approaches for implementing manufacturing processes that are closer to customers or consumers (urban manufacturing).

While products become more and more customised, the **end-to-end integration of manufacturing networks** is important, including logistics, which is a critical factor for unleashing the potential of very flexible distributed production. Made in Europe will develop technologies and methods to enable dynamic and sustainable value networks by the continuous and secure integration of digital technologies (5G, distributed ledgers, AI, etc.) into legacy approaches, supporting hardware and software lifecycle optimisation of products and manufacturing systems. This will lead to transparency, trust, and data integrity along the product and manufacturing lifecycle.

The Research & Innovation Objectives associated to Specific Objective 3 are described in section 2.3.

1.3.3.4 Specific Objective 4: Human-centred and human-driven manufacturing innovation

Humans are at the core of the **innovation process**, increasingly supported by data analytics and decision support systems. Innovation is a process where different processes and disciplines (technological and non-technological) converge into concrete solutions and implementations. Made in Europe will develop new approaches and tools (including strategy management) that strengthen the capability of industrial actors to draw value from external sources of creativity, including start-up companies.

Design and development of advanced technologies will consider the **role of the workforce** at the earliest stages and will consider the available or required additional skills of the people involved. The full benefit of new tools based on advanced technologies can only be achieved by designing new work practices and by involving employees in the co-design. It is, for instance, of great importance to investigate how human knowledge and skills can complement Artificial Intelligence solutions and how smooth human-AI or human-robot interaction can take place. Made in Europe will improve human-device interaction using augmented and virtual reality and digital twins. It will also study human-technology complementarity in achieving excellence in manufacturing.

The implementation of innovative solutions is often subject to reluctance, either associated with potential failure or because decision-makers and/or the workforce are faced with the unknown. **Change management approaches** are required to provide clear insights into the risks and benefits that are associated with change while involving all stakeholders in the process. This should also be associated with anticipating the required skills. Intelligent technologies will need to adapt to their users, while also addressing privacy and understanding workers. It is also important to empower and engage workers to co-design future tools and work practices, and to consider personal preferences in the process of manufacturing innovation and change management. Made in Europe will define such change management approaches.

The Research & Innovation Objectives associated to Specific Objective 4 are described in section 2.4.

1.4 Key technologies and enablers of the Made in Europe Partnership

The integration of technologies and multidisciplinary collaborative are a key characteristics of the Made in Europe Partnership.

The following set of key technologies and enabling approaches will play a key role in achieving the main and the associated policy objectives of the Partnership.

- **Advanced smart material and product processing technologies, and process chains (additive manufacturing, joining, shaping, structuring, surface tailoring, etc.)**
- **Smart mechatronic systems, devices and components**
- **Intelligent and autonomous handling, robotics, assembly and logistic technologies**
- **De-manufacturing, recycling technologies, and life-cycle analysis approaches**
- **Simulation and modelling (digital twins) covering the material processing level up to manufacturing system, and factory and value network level from design until recycling.**
- **Robust and secure industrial real-time communication technologies, and distributed control architectures and standardized equipment protocols as OPC-UA**
- **Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing**
- **New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability**
- **A skilled workforce**
- **Standards**

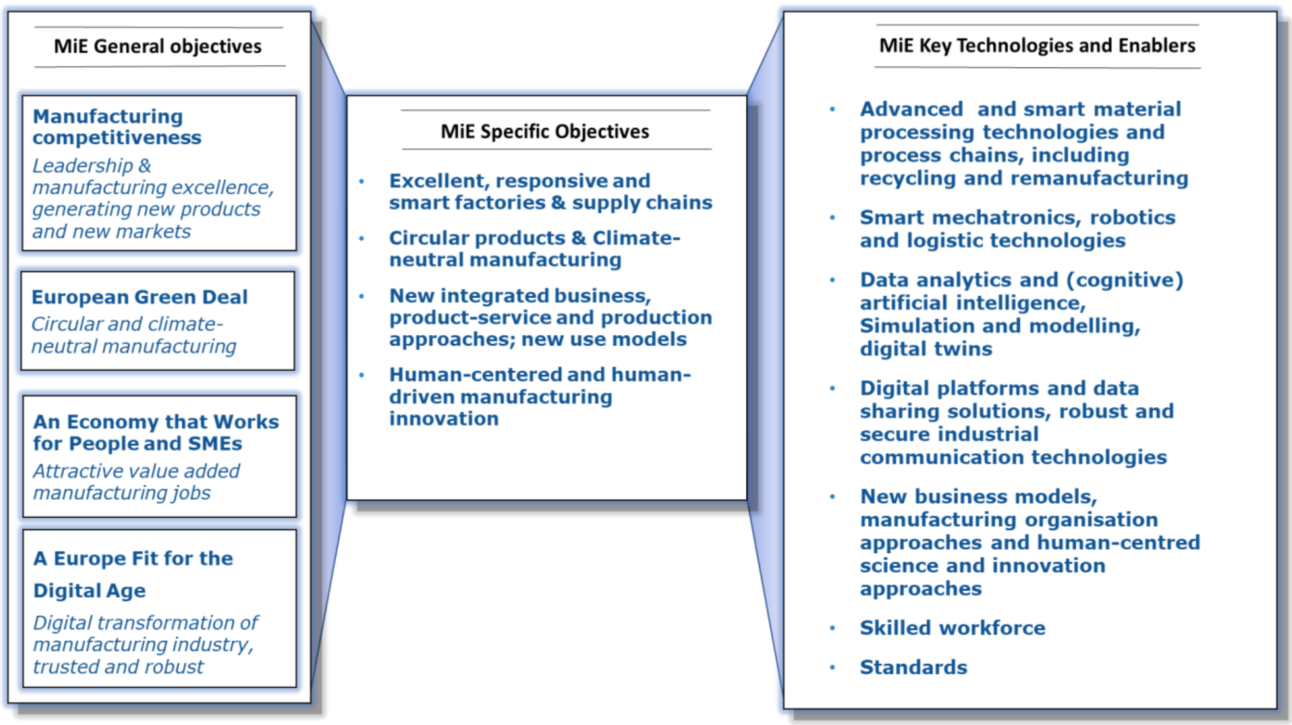

Figure 4: The Made in Europe Key Technologies and Enablers, the building blocks leading to innovation and impact via their development and deployment across the Specific Objectives

1.4.1 Advanced smart material and product processing technologies, and process chains (additive manufacturing, joining, shaping, structuring, surface tailoring, etc.)

Advanced smart material and product processing technologies are at the centre of any manufacturing activity; they cover a broad range of manufacturing sectors and products. The combination of materials and process engineering (often supported by advanced simulation) with smart mechatronics (next enabler in the list below) is key. Bio-inspired or bio-integrated manufacturing is an example of new developments, while also, the so-called ‘traditional material processing technologies’, that have been incrementally but significantly improved towards ‘high performance’ material processing technologies over the past decades, play an important role in manufacturing innovation. ‘Younger’ technologies such as photonics or other physical or chemical processes must be integrated in hybrid, flexible, and robust process chains.

1.4.2 Smart mechatronic systems, devices and components

Smart mechatronic systems, devices and components are at the core of multi-technology approaches, where electronics and software (including (micro-)sensors and (micro-)actuators, local data processing or edge computing devices) are enhancing the accuracy, speed, energy-efficiency etc. of the manufacturing systems, and where these manufacturing systems are connected to ICT solutions and human decision makers in order to optimise the operation of the factories from a multitude of perspectives. Here open source solution and standards are gaining rapidly importance, as compared to vendor lock-in situations that happened sometimes in the past. Products offerings therefore become more data-driven value-added services as predictive maintenance, machine learning, all using data analytics.

1.4.3 Intelligent and autonomous handling, robotics, assembly and logistic technologies

Factory automation approaches – in synergy with the role of humans in the factory – are evolving rapidly, not least through advances in connectivity, data analytics and cognitive approaches. Advanced handling and logistic approaches within and around factories have a big impact on their performance.

1.4.4 De-manufacturing, recycling technologies, and life-cycle analysis approaches

These technologies, tools and knowledge-based methods should recover, re-use, and upgrade functions and materials from high-tech products (including capital goods). Product design and manufacturing engineering should anticipate end-of-life strategies.

1.4.5 Simulation and modelling (digital twins) covering the material processing level up to manufacturing system, and factory and value network level from design until recycling.

Advances in the physical understanding of the behaviour of materials and mechatronics systems and the associated models are enhanced by real time monitoring, data collection and artificial intelligence. Predictive model-based approaches will be deployed from machine level up to supply chain level.

1.4.6 *Robust and secure industrial real-time communication technologies, and distributed control architectures and standardized equipment protocols*

This includes peer-to-peer communication approaches, distributed ledger technologies for industrial applications, wireless communication technologies, including 5G, standardised equipment protocols such as OPC-UA. Specific application requirements such as latency, safety aspects, etc should be considered.

1.4.7 Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing

Data analytics, artificial intelligence/machine learning and the deployment of digital manufacturing platforms are enabling the provision of services that support manufacturing in a broad sense. The Made in Europe Partnership will build on the actions that have been initiated at the end of Horizon 2020, aiming at a broad industrial application-oriented deployment of these technologies, taking account requirements of SMEs as well as the needs for sovereign European industrial data-ecosystems

1.4.8 New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability

The introduction of innovative systems, products and services, where the product can be a manufacturing asset or an innovative consumer good, essentially relies on all of the above - mentioned technologies but need to be complemented by non-technological innovation. Sharing of data among people or legal partners in the value chain should consider regulatory aspects and boundary condition. Also, the implementation of advanced solutions requires migration approaches or 'pathways' from as-is situation towards innovative solutions.

1.4.9 A skilled workforce

Besides the whole range of innovative technologies and novel approaches and concepts, a major enabler of competitive and sustainable manufacturing in Europe is the human workforce, from factory floor to value network operation. New work practices such as co-design and advanced human-machine collaboration require new skills, re-skilling and upskilling. Hence, skills aspects will be addressed across the entire MiE programme.

1.4.10 Standards

Integration is a key characteristic of innovation as well as a key requirement for introducing innovative solutions into a legacy manufacturing context. Standards are key enablers for realising efficient integrated solutions and for assuring the take-up of these technologies and solutions among a broad and diverse manufacturing eco-system. Standards play a key role in areas such as cybersecurity, health & safety, quality, etc… Therefore, the actions carried out under the Made in Europe Partnership will make sure that existing standards are taken into account, generating herewith also input for standards development or revisions.

Note: The described set of enabling technologies provides clear pointers to existing PPPs or initiatives that focus on particular enabling technologies, for example: photonics, electronic systems and components, 5G, Cybersecurity, Big Data and AI, Robotics, and HPC.

1.5 Contribution to European Union and United Nations policy objectives

The Made in Europe Partnership will support and directly contribute the following EU policies:

(i) A New Industrial Strategy for Europe
(ii) The European Green Deal
(iii) Europe fit for the digital age
(iv) An economy that works for people

Indirectly, the Made in Europe Partnership also contributes to the EU policies ”Promoting our European way of life“, “A stronger Europe in the world”, and “A new push for European democracy“.

The following sub-chapter will explain in more detail how the Made in Europe Partnership will significantly contribute to these EU policies; moreover they also contribute to the UN Sustainable Development Goals.

1.5.1 A New Industrial Strategy for Europe: European Leadership and manufacturing excellence, generating new products and new markets

The new EU Industrial strategy aims at improving the European industry's global competitiveness. Competitiveness is also a top priority for the Made in Europe Partnership. Any European manufacturing company has a constant need to strive for excellence and improvements in productivity and quality. This requires producing top quality goods, being highly efficient in terms of costs and resources, while being responsive to the market & customer needs, and using and offering creative and innovative solutions. More than ever companies can only achieve this via cooperation and strong integration in value or knowledge networks. The pre-condition for competitiveness is that European industry can act autonomously and has access to first-class technologies, advanced materials, processes and methodologies, preferably from European sources.

Innovative, sustainable and affordable products are only possible when reliable and performant manufacturing technology is available, which in turn ensures the integration of key technologies, fast and smooth upscaling and conformity with societal requirements. In future, products (incl. machines and components) will have to meet increasing requirements in terms of customisation, flexibility, transparency and environmental impact.

The Made in Europe partnership will provide full attention to the relationship between material and product innovation and production process innovation along their lifecycles. This involves closing the loop between product and production process innovation in the short-term (for example by ‘design for manufacturing’) as well as anticipating longer-term technology roadmaps for product sectors, aligning them with production technology roadmaps. Moreover, it will account for new servitisation business models where the design and manufacturing of products, the leasing and remote monitoring/maintenance and return of products leads to new paradigms. Hence, the impact of the partnership will be maximised across different product sectors from material producers up to OEMs and service providers.

Within Made in Europe, the **specific objective 1 'Excellent, responsive and smart factories and supply chains'** is the centre of focus with respect to contributing to **the policy 'New Industrial Strategy for Europe'**. The associated research and innovation actions will address key priorities such as:

- Zero-defect and zero-downtime high-precision manufacturing, including predictive quality and non-destructive inspection methods
- Advanced Manufacturing processes for smart and complex products
- Manufacturing for miniaturisation and functional Integration
- Scalable, reconfigurable and flexible first-time-right manufacturing
- Artificial intelligence for productive, excellent, robust and agile manufacturing chains - Predictive manufacturing capabilities & logistics of the future
- Data 'highways' and data spaces in support of smart factories in dynamic value networks

However, the other specific objectives contribute also significantly to the policy **'New Industrial Strategy for Europe'**, for instance:

- Specific objective 2 'Circular products & Climate-neutral manufacturing', with priorities such as:

    - Manufacturing with new and substitute materials
    - Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks

- Specific objective 3 'New integrated business, product-service and production approaches; new use models', with priorities such as:

    - Collaborative product-service engineering for customer-driven manufacturing value networks
    - Secure communication and IP management for smart factories in dynamic value networks

- Specific objective 4 'Human-centered and human-driven manufacturing innovation', with priorities such as:

    - Human & technology complementarity and excellence in manufacturing
    - Technology validation and migration paths towards industrial deployment of advanced manufacturing technologies by SMEs

1.5.2 European Green Deal: Circular and climate-neutral manufacturing

The Made in Europe Partnership will be one of the key research & innovation programmes to accelerate reaching some of the essential goals of the European Green Deal: making the EU climate neutral by 2050, boosting the economy through green technology, creating sustainable industry and transport, and cutting pollution.

European Industry will undergo a drastic reform in the coming years associated with huge investments in new innovative technologies and integrated approaches. Climate change, resource scarcity and the impact of waste on the earth's ecosystems will change manufacturing paradigms. Made in Europe will develop new technologies and methods for circular, low-environmental impact and low-carbon approaches while increasing energy and resource efficiency in manufacturing. Energy and power technologies will further enable resilient and sustainable manufacturing, by deploying integrated approaches which cover life-cycles and link different sectors, disciplines and ecosystems. In addition, new production systems and concepts will be needed when manufacturing increasingly uses recycled materials or when remanufacturing happens.

The transformation to a circular economy will lead to the development and introduction of innovative business models, which will furthermore rely on the data economy. Likewise, environmental-friendly high-quality repairable products require manufacturing excellence and flexibility. The Made in Europe contributions to the European Green Deal go hand in hand with its contributions to the New Industrial Strategy for Europe and to a Europe Fit for the Digital Age.

Within Made in Europe, the **specific objective 2 'Circular products & Climate-neutral manufacturing'** is the centre of focus with respect to contributing to the policy **'European Green deal'**. The associated research and innovation actions will address key priorities such as:

- Ultra-efficient, low energy and carbon-neutral manufacturing
- De-manufacturing, re-manufacturing and recycling technologies for the circular economy
- Manufacturing with new and substitute materials
- Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks
- Digital platforms and data management for circular product and production-systems life-cycles

However, the other specific objectives contribute also significantly to the policy **'European Green deal'**, for instance:

- Specific objective 1 'Excellent, responsive and smart factories and supply chains', with priorities such as:
    - Zero-defect and zero-downtime high-precision manufacturing, including predictive quality and non-destructive inspection methods
    - Scalable, reconfigurable and flexible first-time-right manufacturing

- Specific objective 3 'New integrated business, product-service and production approaches; new use models', with priorities such as:
    - Manufacturing processes and approaches near to customers or consumers (including urban manufacturing)
    - Transparency, trust and data integrity along the product and manufacturing life-cycle

- Specific objective 4 'Human-centered and human-driven manufacturing innovation', with priorities such as:

- Technology validation and migration paths towards industrial deployment of advanced manufacturing technologies by SMEs

1.5.3 A Europe Fit for the Digital Age: Digital transformation of manufacturing industry, trusted and robust

The Made in Europe partnership aims to boost the digital transformation of the manufacturing industry. This transformation involves the deployment of a vast range of advanced technologies and organisational, human and skills-related enablers. For decades, manufacturing operations profited from increased physical automation of physical operations, and now the fourth industrial revolution brings new digital technologies (e.g. AI, IoT, CPS) into use and enables demand-driven operations and true flexibility in the manufacturing industry. In addition, new data-driven business models will emerge.

The ‘digitalisation of manufacturing’ is a key component of the transformation of the manufacturing industry. Digital technologies and approaches connect people, devices, machines and enterprises, including concepts such as the 'Industrial Internet', 'digital manufacturing platforms', the 'Industrial Internet of Things' (IIoT), artificial intelligence/machine learning, digital twinning, etc. The Partnership will bring together operational technology (OT) and information technology (IT) for manufacturing and will provide inspiring demonstrators, pilot sites, and field labs. The Partnership will support industrial Digital Innovation Hubs that fuel the digital transformation of manufacturing and engage SMEs in the digital transformation.

Within Made in Europe, all specific objectives contribute to the policy **‘A Europe Fit for the Digital Age’**. The associated research and innovation actions will address key priorities, for instance:

- Specific objective 1 ‘Excellent, responsive and smart factories and supply chains’, with priorities such as:
    - Zero-defect and zero-downtime high-precision manufacturing, including predictive quality and non-destructive inspection methods
    - Scalable, reconfigurable and flexible first-time-right manufacturing
    - Artificial intelligence for productive, excellent, robust and agile manufacturing chains - Predictive manufacturing capabilities & logistics of the future
    - Data ‘highways’ and data spaces in support of smart factories in dynamic value networks

- Specific objective 2 ‘Circular products & Climate-neutral manufacturing’, with priorities such as:
    - Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks
    - Digital platforms and data management for circular product and production-systems life-cycles

- Specific objective 3 ‘New integrated business, product-service and production approaches; new use models’, with priorities such as:

  - Collaborative product-service engineering for costumer-driven manufacturing value networks
  - Manufacturing processes and approaches near to customers or consumers (including urban manufacturing)
  - Transparency, trust and data integrity along the product and manufacturing life-cycle
  - Secure communication and IP management for smart factories in dynamic value networks

- Specific objective 4 'Human-centered and human-driven manufacturing innovation', with priorities such as:
  - Digital platforms and engineering tools supporting creativity and productivity of manufacturing development
  - Improving human device interaction using augmented and virtual reality and digital twins.
  - Human & technology complementarity and excellence in manufacturing
  - Manufacturing Innovation and change management
  - Technology validation and migration paths towards industrial deployment of advanced manufacturing technologies by SMEs

1.5.4 An Economy that Works for People: Attractive value-added manufacturing jobs

With increasing challenges and introduction of new technologies, the need for adequate skill sets in manufacturing continues to grow. However, manufacturing companies currently face shortages of skilled workers. Insights into future job profiles and skills-related challenges and solutions need to be continuously planned for and responded to. While manufacturing is already under transformation to knowledge work, future innovations need to provide a better understanding as to how employees create and modify their jobs and how new technologies and social innovations are introduced and used by the current workforce. The twin ecological and digital transitions will require reshaping human-machine relations, preparing people with the right capabilities, and providing the right tools and interfaces. In this context, digitalisation can provide work communities with more productive tools. Operational technology (OT) employees need to receive proper training to use information technology (IT). With the speed of digitalisation, all employees need continuous training at work. Older employees, in particular, are at risk as they did not receive proper training in digital technologies while at school.

In addition to shortages of skilled workers, the shortage of experts such as data scientists and engineers is a major barrier for European companies.

Within Made in Europe, the Specific objective 4 'Human-centered and human-driven manufacturing innovation' is the centre of focus with respect to contributing to the policy **'an Economy that Works for People'**. The associated research and innovation actions will address key priorities, for instance:

- Digital platforms and engineering tools supporting creativity and productivity of manufacturing development

- Improving human device interaction using augmented and virtual reality and digital twins.
- Human & technology complementarity and excellence in manufacturing
- Manufacturing Innovation and change management
- Technology validation and migration paths towards industrial deployment of advanced manufacturing technologies by SMEs

However, the other specific objectives contribute also significantly to the policy **'an Economy that Works for People'**, such as

- Specific objective 1 'Excellent, responsive and smart factories and supply chains', with priorities such as:
    - Artificial intelligence for productive, excellent, robust and agile manufacturing chains - Predictive manufacturing capabilities & logistics of the future

- Specific objective 2 'Circular products & Climate-neutral manufacturing', with priorities such as:
    - Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks
    - Digital platforms and data management for circular product and production-systems life-cycles

- Specific objective 3 'New integrated business, product-service and production approaches; new use models', with priorities such as:
    - Collaborative product-service engineering for costumer-driven manufacturing value networks
    - Manufacturing processes and approaches near to customers or consumers (including urban manufacturing)

1.5.5 Links to UN Sustainable Development Goals

Beyond contributing to EU policies, the Made in Europe Partnership will also address the UN Sustainable Development Goals. It will make contributions to the following **5 SDGs**, which are relevant to the manufacturing industry:

SDG 4: Quality Education:
Made in Europe brings together companies with research institutes and universities and their experts on research and training. All parties will benefit from positive spill-over effects from their work under Made in Europe to the daily training and education of their employees.

SDG 8: Decent work and economic growth:
Manufacturing offers prosperous and meaningful employment, involving human-machine interaction. Made in Europe puts the human dimension central in manufacturing, ensuring that machines serve the purposes of humans. Companies of all sizes can employ the people with the expertise, skills and talents they need to be successful.

SDG 9: Industry, Innovation and Infrastructure:
In order to be successful, European companies of all sizes need to have access to first-class infrastructures, innovative technologies and collaboration networks. They need stable, profitable, non-dependent and innovation-friendly conditions. Made in Europe will provide access to technological excellence, to Europe-wide cooperation, contributing to a European manufacuting innovation space.

SDG 12 Responsible Production and Consumption:
Industry must make substantial progress toward circular and carbon-neutral production processes, while providing affordable, innovative and green products. Made in Europe will develop clean technologies, excellent engineering instruments for a circular economy and improve the understanding of both natural boundaries and the impact of technologies

SDG 13 Climate action:
Industry is responsible for around one third of greenhouse gas emissions, but is also producer of new, carbon-avoiding technologies. Made in Europe will contribute both by developing carbon-neutral processes and enabling the production of carbon-neutral products and services.

Figure 5 Links to UN Sustainable Development Goals

1.6 Expected impacts

The main expected impacts from the Made in Europe partnership arise from its contributions to EU policy objectives. **The partnership aims for a European manufacturing industry which**

- Is world-wide competitive, resilient and adaptive;
- Is technology-leading;
- Is resource-efficient and has integrated circular economy principles in all its activities;
- Leads in the implementation of digital solutions;
- Offers high-quality jobs to well-skilled people, in enterprises of all sizes;
- Brings prosperity to all regions of Europe.

In short, the Partnership aims for a **competitive, green, digital, human-centric manufacturing sector**.

Being a part of the Manufacturing industry, the Made in Europe-Initiative contributes the overall objectives of this sector in terms of CO2-reduction, material & energy efficiency and competitiveness. In particular, Made in Europe is:

- fully committed to make manufacturing carbon-neutral by 2050
- fully committed to maintain an industrial share of the economy of 20%
- fully committed to reduce the use of primary materials by 20% in the next decade.
- fully committed to increase technological leadership and resilience of its ecosystems

The performance of the Made in Europe Partnership will be monitored through KPIs. KPIs will be monitored at macro-economic, programme, project and company level. The partnership will gather relevant industry data and will report on the KPIs and progress of their achievement. This will be reported in the annual Monitoring Reports and will be supported by annual surveys.

KPIs will be measured by data from expert sources for all relevant manufacturing segments. Programme KPIs will measure the effect of the Made in Europe partnership achieved via exploitation, deployment, and implementation of its results. It will be measured by expert estimates.

The following Key Performance Indicators are defined for the European Partnership and will be included in monitoring and reporting

Objective		KPI #	KPI definition	Proposed Target
Ensuring manufacturing excellence	Advance technologies for green, flexible and resilient manufacturing in all sectors	KPI 1	num. of demonstrators targeting zero defect and zero downtime manufacturing	50 demonstrators, with scrap rate reduction of up to 20%; reduction by 10% on the amount of labour on defect identification and finishing
		KPI 2	num. actions for production of smart and complex products	10 demonstrators and actions
		KPI 3	num. demonstrators and actions targeting green and resilient manufacturing (either factory level or entrie supply chain)	80 demonstrators covering at least one the subitems 50 demonstrators, with 10-25% less material use 50 demonstrators, with 10-25% less energy use 50 demonstrators, with 15-30% less water use 50 demonstrators, with 20-30% less industrial waste 50 demonstrators, with 35% of renewable energy
		KPI 4	num. high TRL demonstrators per sectors	30 demonstrators; each project or demonstrator addresses at least three end-user sectors
		KPI 5	num. demonstrators targeting De-manufacturing, re-manufacturing and recycling technologies for more efficient manufacturing	50 demonstrators
	Build flexible and resilient supply chains	KPI 6	num. demonstrators targeting supply chain innovations	50 demonstrators
		KPI 7	num. demonstrators targeting improvement of response-time	50 demonstrators
Mastering the digital transformation	Ensure uptake of digital technologies for manufacturing	KPI 8	num. demonstrators and activities developing AI, data analytics tools and use	80 demonstrators covering at least one the following items: Digital platforms Artificial intelligence, machine learning Simulation & modelling (digital twins) Robust and secure industrial real-time communication technologies
	Support the green and digital transition of a wide range of manufacturing Sector in	KPI 9	num. demonstrators encompassing virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks	40 demonstrators

	different EU regions			
Circularity and Carbonneutrality	Reduction in use of resources, materials, energy, water and waste	KPI 10	num. new circular value chains	30 cases demonstrating new innovative circular value chains
Creating attractive and value added jobs	Ensure Human and technology complementarity and excellence in manufacturing	KPI 11	num. of demonstrators using Digital platforms and engineering tools, supporting creativity and productivity of research &development processes as well as leading to less time spent modelling digitally manufacturing business processes and eilimnating interfaces	30 demonstrators
	Support initatives that empower workforce with new skills	KPI 12	num. demonstrators and actions targeting the training of workforce in new technologies	60 demonstrators
		KPI 13	num. jobs created targeting new skills and job profiles	100 % of project addressing new skills, new knowledge or new job profiles 80 new skills, new knowledge or new job profiles demonstrated
		KPI 14	Increase in safety and welbeing in the factory	50% demonstrators showcase a higher level of safety/well-being or work satisfaction of the workers (based on employee feedback)
Management and dissemination	Contribute to standardisation, inluding the use and assessment of standards	KPI 15	% of projects and num. of additional activities setting up a path to influence and support standardisation, regulation and certification	100% of projects address standards (either contribute or use relevant standards) 10% of projects deliver a standardisation specific document agreed with (CEN Workshop Agreement, Technical specification and technical report) within 3 years from the end of the project.
	Contribute to other activities (Conferences, workshops, training activities, …)	KPI 16	num. of additional activities of workshops of at least 50 attendees	30 workshops
		KPI 17	num. of additional activities of conferences of at least 300 attendees	8 to 10 conferences

KPI ID	KPI Definition	Baseline (beginning of the partnership):	Target (end of the partnership):
Companies KP1	Percentage of companies involved in MiE implementing innovative green and digital technologies related to the programme	Maturity indexes to be defined at the beginning (see also MC-KPI-5 for digital)	all companies (100%) to shift at least one level higher in the index; 40% to shift two levels
Companies KP2	Increase in turnover of company involved in MiE, compared to the average of the manufacturing sector (NACE C)	sales figures in 2020	higher sales figures, as compared to companies in the same market segment
Companies KP3	number of companies involved in MiE demonstrating 60-70 % reduction of CO2 emissions	CO2 emissions in 1990 of companies in question	at least 200 companies demonstrating 60-70% reduction
Companies KP4	number of companies involved in MiE demonstrating 10-20 % higher reduction of industrial waste generated, as compared to all manufacturing industry	Waste generated in year 2020 of companies in question	at least 250 companies demonstrating 10-20% reduction
Companies KP5	% Increase in investment for digitalisation by companies involved in MiE	Associated digitalisation to Maturity indexes (links to MC-KPI-1)	higher investment figures, as compared to companies in the same market segment
Companies KP6	Number of new robust value chains solutions; which might include interoperability, platforms, reshoring sucess stories diversification cases or concrete solutions/products which are meant to compete with non-european solutions/products	0	30 solutions demonstrated

General note about baselines and KPIs:

Retained project proposals will need to define clear targets such as baseline (AS-IS) values of the actual manufacturing or associated processes that are covered by the project proposal and targets defined in percentages that are significant for these covered processes and that do not only result from implementing state-of-the-art technologies or approaches.

Baseline values will be determined for each demonstrator case at the beginning of each project. Target KPIs values may differ depending on the particular scope of the call topic and may even be different from one demonstrator to another.

Companies will profit from monitoring and assistance, in terms of Industry 4.0-readiness level or 'Factories of the Future maturity levels'. Methodologies and approaches [3] will be developed and manufacturing companies across Europe will benefit from the achievements of the Made in Europe Programme.

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[3] There are already several existing or emerging maturity levels available:
About 50 maturity scales described by the ADMA scan (http://www.adma.ec/)
The maturity levels described by the DigiMaturity tool (https://digimaturity.vtt.fi/)
The ConnectedFactories Pathways to digital manufacturing
https://www.connectedfactories.eu/pathways-digitalisation-manufacturing

1.7 The Necessity for a European Partnership

European manufacturing is extremely diverse. Technologies are numerous, professions are distinct, application sectors differ from each other and range from food processing to clean-room environments. Yet, there are many topics and challenges which connect manufacturing experts across different disciplines. Therefore, there are also many different forms of cooperation on a European level for specific technologies/sectors, in addition to the cooperation that takes place on a national level.

In order to bundle and pool together such diverse expert groupings, a European manufacturing initiative is needed. It would unite all actors from the many communities and initiatives in joint cooperation on a European level. A co-programmed Partnership would suit best to realise this cooperation among the wide and dispersed manufacturing community.

As compared to standard Horizon Europe calls, a Partnership approach provides the following advantages:

- A Partnership will enable **a structured and strong cooperation**, between on the one hand the European Commission and the Member States (public side) and on the other hand the association that represents the manufacturing research and innovation community (private side). This Partner association will not only **mobilise the stakeholders on a continuous basis** for providing guidance regarding the most critical challenges that need to be addressed by the Partnership; the Partner association moreover **increases the efficiency of the stakeholder community** in tackling these challenges, not only in projects funded via the Partnership, but also in projects that are either publicly funded via other programmes or privately financed, in particular in the stages that are **close to the commercialisation and up-scaling phase** of the developed technologies and approaches.

- A Partnership will **create the expected impacts** to address the challenges faced by the European manufacturing industry. Challenges such as the twin ecological and digital transitions can only be successfully mastered through coordinated, strategic cooperation on a European level.

- A Partnership will **provide strategic orientations** for the whole European manufacturing community, i.e. beyond the direct participants in the partnership themselves, through EU-wide definition of priorities, roadmaps, and inspiring cross-border initiatives. The Made in Europe Partnership will act as a “manufacturing lighthouse”, which will give strategic guidance to decision-makers on a commercial, academic, and political level.

- A Partnership will **align and coordinate R&I efforts across Europe**. We need a common understanding and aligned investments, e.g. for sustainable manufacturing, standardised approaches in data sharing, development of manufacturing skills, human-technology systems, worker issues, and training arrangements.

- A Partnership will **lead to Calls for Proposals that are relevant to the manufacturing sector**. The roadmap-based approach proved to work well for the manufacturing community up to now. Before the existence of the FoF PPP, call topics were considered to be too academic and less industry-relevant, hence the impact was rather small. Companies were not prepared and did not know when relevant calls would appear. Calls were only known to a small, select group of people. It is thanks to call topics based on a strategic roadmap developed through industry and research collaboration, that they became of higher quality and attracted higher industrial participation than in the past. When projects are executed today, they are more industry-oriented and with a higher industry participation, which in turn increases their impact in terms of industrial competitiveness, sustainability, skills, etc.

- A Partnership will **act as a unifying mechanism**, which would otherwise not exist. It creates trust between actors, which leads to better cooperation and more impact. The Partnership allows to best leverage for the collective expertise and assets across its participating organisations to support companies in commercialising innovation.

- A Partnership will **offer Europe counterbalance against initiatives of global competitors**, e.g. Made in China 2025, via a visible, strategic initiative on manufacturing. By bringing together the best European actors, Europe's industry will be able to stay on eye-level with global competitors, which benefit from huge internal markets and state support for manufacturing. No Member State alone will be able to make the necessary investments or provide the excellence needed.

- A Partnership will **offer Europe a mechanism to strengthen the sovereignty of its manufacturing sector**. Cooperation on a European level will reduce external dependencies of the European industry. The partnership will provide strategic orientation, inspiration, and the best available technology for the manufacturing sector.

- A Partnership will **support other, strategic initiatives**. Manufacturing is not only an essential part of several strategic value chains, but also a strategic sector on its own. To support European initiatives such as battery production, Industrial Internet of Things, or the automotive sector, a strategic, European initiative on manufacturing is essential.

- A Partnership will **foster cross-fertilisation among national programs and projects**. National and regional initiatives are highly important; in addition to that, a European-level manufacturing initiative for applied collaborative research is needed. The Made in Europe Partnership will be the platform for national initiatives to learn from each other, in a way to compete with each other and achieve cross-fertilisation. Moreover, cooperation on a European level enables researchers from less industrial regions/cities to get in touch with researchers from more high-tech regions/cities.

1.8 Partner composition and target group

The Made in Europe Partnership will address the wider manufacturing stakeholder community in its full complexity and richness. Consequently, the target group is very broad.

Industry:
- Producers of productions technologies, such as machine tools, robotics, handling and logistics solutions, etc.
- Producers of industrial information technologies including IoT enabled devices and software in the cloud or embedded on the edge.
- Manufacturing companies in various application sectors, such as automotive, aerospace, consumer goods etc
- Industry-driven clusters and associations
- All company sizes, from start-ups over SMEs to multinationals
- etc

The scope of the Made in Europe Partnership will be broader than the Factories of the Future PPP in Horizon 2020. While the sectors that were as in the Factories of the Future PPP will continue to be served, in addition more application sectors will be encouraged to participate, such as:

- Manufacture, processing and packaging of food products and beverages, including bottling and sorting
- Manufacture of textiles and wearing apparel
- Manufacture of furniture and products of wood
- Manufacture of paper and paper products
- Manufacture of rubber and plastic products
- Manufacture of sophisticated structures dedicated for the construction industry
- Waste processing
- Repair and installation of machinery and equipment

Research Technology Organisations /Academia:
The Partnership will attract and involve Research Technology Organisation and Universities which perform applied research.
Compared to the past, the Partnership will not involve only technology experts, but will the also include experts from other faculties in management, social science etc.

Expert contributions coming from other relevant perspectives:
Expert opinions from other organisations will be welcome (beside industry and academia). Trade Unions, Labor organisations, Foundations, Standardisation bodies, local authorities and other organisations will contribute too.

Regarding geographical coverage, the Made in Europe Partnership will aim at finding the right balance between not compromising on the excellence criteria, but still doing an “extra effort” in countries which so far have been under-represented in EU research.

Looking at the international level, dialogues and interchanges will happen at the level **CIRP**[4] and the **World Manufacturing Forum**[5]. These interactions of world-wide level will be both a chance to showcase what the European Made in Europe Partnership is doing and a opportunity to find international partners in areas where this makes sense from a European perspective.

The Economic weight of the target group:

The Made in Europe Partnership will address some 12-14 manufacturing sectors which generate an economic outpour of approximately 3200 billion Euros and employ some 16 million employees.

Excellence

While excellence will be the main criterion in the open competition for project funding, the Made in Europe Partnership will actively support the involvement of partners from countries, which so far have been under-represented in EU research. In an excellent consortia, industrial partners with well-balanced capability learn, take over and commercialise technology and knowledge from research institutions, while contributing their specific expertise to the research project. Similarly, partners from the countries mentioned above, capable of performing relevant tasks in the project, will improve their excellence in the collaboration with other excellent partners.

Ensuring Impact beyond 2027

EFFRA and its members will be safeguarding all outputs and insights which stem from Made in Europe Partnership activities. Even beyond 2027, when the Partnership will formally end, EFFRA and its members are engaging in further exploiting the results that will be produced in the years 2021-2027.

The long-term impact of manufacturing industry lies in the creation of sustainable growth and jobs. Europe needs to drive for manufacturing innovation as it has a strategic importance for wellbeing, environment and business, both direct and indirectly. Made in Europe will have an important role in combining the scattered efforts in Europe and help European manufacturing value chains and the regional and local manufacturing innovation ecosystems to take the necessary steps towards sustainability and competitiveness. As the manufacturing sector is capital-intensive and dominated by SME's, the business impacts of the partnership will take time. Also, while steps towards climate neutral industry needs to be fast, reaching an high level of circularity means a system-level-change that is time-intensive. Therefore, impacts of the partnership shall extend well beyond 2027.

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[4] https://www.cirp.net/

[5] https://www.worldmanufacturingforum.org/

2 Research & Innovation Objectives of the Made in Europe Partnership

In the following sections, a set of Research & Innovation Objectives are described for each of the four Made in Europe Specific Objectives:

- **Specific Objective 1: Efficient, responsive and smart factories and supply chains**
- **Specific Objective 2: Circular products & Climate-neutral manufacturing**
- **Specific Objective 3: New integrated business, product-service and production approaches; new use models**
- **Specific Objective 4: Human-centred and human-driven manufacturing innovation**

The Research & Innovation Objectives provide the input for the preparation of future work programmes.

(It should be noted that one Research & Innovation Objective can be relevant for more than one Specific Objectives. However it was chosen to allocate the R&I Objectives under its 'main' Specific Objective)

2.1 Research & Innovation Objectives under Specific objective 1: 'Excellent, responsive and smart factories & supply chains'

This Specific Objective includes the following Research & Innovation Objectives:

- **R&I Objective 1.1: Data 'highways' and data spaces in support of smart and real-time connected factories in dynamic and robust value networks**
- **R&I Objective 1.2: Scalable, reconfigurable and flexible first-time right manufacturing**
- **R&I Objective 1.3: Zero-defect and zero-down-time manufacturing, including predictive quality and non-destructive inspection methods**
- **R&I Objective 1.4: Artificial intelligence for productive, excellent, robust and agile manufacturing chains - Predictive manufacturing capabilities & logistics of the future**
- **R&I Objective 1.5: Advanced manufacturing processes for smart and complex products**
- **R&I Objective 1.6 High precision manufacturing for miniaturisation and functional Integration**

Figure 6: Research & Innovation Objectives allocated to 'Specific Objective 'Excellent, responsive and smart factories & supply chains'

2.1.1 R&I Objective 1.1: Data 'highways' and data spaces in support of smart and real-time connected factories in dynamic and robust value networks

General objectives and scope

Flexible and agile manufacturing is a key priority for reducing manufacturing lead time and costs, while supporting low-volume demand-driven highly customised production of high-tech systems (manufacturing equipment/tools, medical instruments, automotive, aerospace parts, etc). To achieve these objectives, highly automated customer and supply chain management is a critical ingredient that can only be realised with adequate digital infrastructure. Seamless and secure traceability of supply chain operations require deployment of digital technologies. A key requirement of such a digital infrastructure is the assurance of digital communications across factory boundaries, including access control, protection against cyber-attacks, data privacy and integrity, intellectual property protection, etc (See also R&I Objective 3.3 'Transparency, trust and data & IP integrity, open systems and cybersecurity and along the product and manufacturing life-cycle').

Highly complex products of original equipment manufacturers (OEMs) are mostly manufactured in (regional) ecosystems with a large number of (100-250) first-tier SMEs and thousands of sub-tier suppliers. In order to obtain robust, resilient value chains, such ecosystems require data spaces with standardised data formats for the exchange of design, manufacturing, logistics and other (digital twin) product/component data to allow for in-bound, real-time deep-chain planning and control for logistic information and design modifications. Suppliers are often part of value chains associated to more than one OEM. Together, multiple value chains form (regional) industrial design and manufacturing ecosystems. Similar for outbound logistics (providing traceability and manufacturing quality data) dataspaces provide the manufacturers with generic means to offer the transparency required by OEMs. The purpose of data highways/data spaces is to avoid that suppliers need to support numerous different interfaces. *Made in Europe* will contribute to realising **responsive value chains** by demonstrating advanced standardised data spaces to support smart factories sharing data with other factories and organisations such as service providers.

This objective is of priority within the European continent in order to become more responsive to global changes, be it pandemics and required medical supplies or be it to provide rapid flexible dual-use manufacturing capability. Given the recent situation regarding the impact of COVID-19 on manufacturing value chains and the impact of interrupts in particular of global value chains, there is an increasing need for rapid deployment and production resilience.

Related Research & Innovation Objectives

- R&I Objective 1.1 is associated to performance-oriented **R&I Objectives, such as R&I Objective 1.3: Zero-defect and zero-down-time manufacturing, including predictive quality and non-destructive inspection methods.**

  In order to increase impact, a data highway and space should be associated to specific manufacturing objectives or application areas. The use of data spaces in value networks of smart factories is expected to be a leading application area. The use of data spaces in servitisation/recycling (associated to 're-use' business models) is more complex given the fact that even more parties are involved.

- R&I Objective 3.3: **Transparency, trust and data & IP integrity, open systems and cyber security along the product and manufacturing life-cycle.**

  Suppliers will need to provide transparency and visibility of their own manufacturing process towards their customers to enable more real-time value chain status information. In addition to automating more and more work cells, each work cell/operation will provide real-time status information within the factory and across factories. Data spaces between factories should provide secure information exchange to only those who are allowed to access the status information.

- Data should also be available for data analytics and artificial intelligence as described in R&I Objective 1.4: **Artificial intelligence for productive, excellent, robust and agile manufacturing chains - Predictive manufacturing capabilities & logistics of the future**.

  The more data is available from manufacturing processes, the better the AI-algorithms become. Data spaces provide a means to share data between more participants and improve AI-algorithms.

Key Technologies and enablers

- Digital Twin models that include design and manufacturing data of individual products and well as digital twins of manufacturing systems.
  - Distinguish the static digital twin describing the non-changing parameters and capabilities of a product/production vs. the dynamic digital twin containing the current status, the gathered data etc..
  - Not only "Digital Twins" are important, but also "Digital Threads" have to be considered, which are actually more challenging. (Digital Threads = a holistic view of an asset's data across its product lifecycle – see also the comment under R&I Objective 2.5 'Digital platforms and data management for circular product and production-system life cycles').

- Data analytics, artificial intelligence, and deployment of digital platforms for data management and sharing
  - Interoperable, cyber secure hybrid IoT architectures with big (small) data analytics capabilities and semantics support for data exchange and knowledge generation. Seamless fusion of data coming from different and heterogeneous data sources, including data spaces, at cross domain and value chain.

- Robust and secure industrial real-time communication technologies
  - Wireless communications, 5G in industrial applications and zero-latency alternatives
  - Cybersecurity: New distributed data security model, addressing data integrity, confidentiality, privacy and non-repudiation.

  - Data storage and computation technologies as homomorphic or multi-party computation to enable IoT sovereignty and safeguard data ownership

- New business and new organisational approaches, associated to regulatory aspects such as safety, data ownership, and liability

  - The complexity of value networks, in parallel with a progressive digitalisation of the entire manufacturing process, requires a huge investment in the data management, sharing along the supply chain and protection. Affordable solutions are critical.

- Standards and standardisation
  - Demonstration should prove the viability of the proposed standards.

- Skills

Additional observations and boundary conditions

- Developments such as International Data Space (IDS) and GAIA-x are highly relevant for this Research & Innovation Objective. Complementary developments, especially providing services acting on different data and models, are expected.

2.1.2 R&I Objective 1.2: Scalable, reconfigurable and flexible first-time right manufacturing

General objectives and scope

The manufacturing industry needs to respond quickly to market disruptions, changing customer demands, fluctuating characteristics of raw materials and components, and advanced emerging technologies that can be potential differentiators. Simultaneously, manufacturing industry is forced to increase quality and efficiency and reduce Total Cost of Ownership. Hence, upgradable and robust manufacturing systems and plants (covering intra-logistics and even supply networks) are necessary for **flexible, responsive and resilient manufacturing**.

Of particular interest is the 'mid-volume' manufacturing, where requirements for high volume production meet production and reconfiguration approaches that are applied for low-volume or lot-size one production. Also, different automation grades are applied for the production of the same product across different continents or regions.

The ability to shift from the prototype and small series production to a flexible mid-volume production will help companies (especially SMEs) to stay more competitive, reduce costs and risk associated to investment as well as to minimise scraps & reworks.

Related Research & Innovation Objectives

- R&I Objective 1.6 **'Data 'highways' and data spaces in support of smart factories in dynamic value networks'**
- R&I Objective 1.1 **'Zero-defect and zero-down-time manufacturing, including predictive quality and non-destructive inspection methods'.**

Key Technologies and enablers

- Smart mechatronic systems, devices and components
  - Modular multi-functional methods and systems associated to life cycle considerations of the production system such as maintenance, repair, spares, etc..
  - Integrated in-line quality control technology (see also R&I Objective 1.3 'Zero-defect and zero-down-time manufacturing, including predictive quality and non-destructive inspection methods').
- Simulation and modelling, digital twins
  - First-time right and flexible production is only possible when having the appropriate and reliable simulation tools at hand to avoid trial and error.
  - Concurrent engineering in Product Development (design, manufacturing, in-service, end of life) and Production Engineering.
  - Model Based Systems Engineering, - Parametric and modular software for manufacturing equipment.
- Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing

    - Flexible control software for planning and operation of scalable, reconfigurable and flexible production systems.
    - AI based technologies for speeding up and improving the set-up and ramp-up phases of the manufacturing process, but also the planning and prediction of product requirements.
    - Machine Learning (ML) solutions leveraging on previous experiences including both supervised and unsupervised solutions. Reinforcement learning based for process set-up and ramp-up performance improvement.
- New business and new organisational approaches
    - Need for affordable solutions applicable for SMEs
    - New methods and approaches for scalable production and supply networks from OEM to the sub-tier suppliers
- Standards and standardization
    - Defined and standardized interfaces of production systems, equipment and modules as well as intralogistics solutions. Many technologies are already available, there is a need generate and promote standards, which also should be adopted by HW and SW vendors
    - Efficient and effective use of ontologies for the digital integration of the value chain (data)
    - Interoperability solutions for brownfield scenarios
- Skills
    - For example, the user-interaction with simulation tools is essential.

Additional observations and boundary conditions

- The relevance of this research objective has been demonstrated by COVID-19. Flexibility and versatility will be more important even in future crises.
- Need for pilot lines, supporting the transformation to "new type of products and new ways of producing".

2.1.3 R&I Objective 1.3: Zero-defect and zero-down-time manufacturing, including predictive quality and non-destructive inspection methods

General objectives and scope

Made in Europe aims to contribute to more excellent, responsive and smart factories and supply chains. Excellent and responsive production combines speed, precision, quality and reliability with flexibility and agility. Manufacturing companies need to produce from very small lot-sizes to big volumes and there is a growing need for the ability to quickly scale up from small to big lot-sizes whilst retaining the required quality in **zero-defect and first-time-right** production.

Made in Europe will provide technologies and methods for zero-defect and zero-downtime manufacturing, including predictive quality and non-destructive inspection methods. Zero defect manufacturing needs a holistic approach in which not only the production process is simulated and monitored, but also the production equipment and peripheral equipment in a fully seamless digital integrated value chain.

Solutions may differ a lot depending on the tolerances allowed in each sector as well as cost, production rate and quality standards. There should always be a clear link between the requirements/specifications and the 'process windows' that deliver the desired manufacturing performance. Research & Innovation actions should identify the need for tailored solutions addressing different levels of complexity to reduce the risk of concentrating only on the 'simplest' cases.

Different kinds of sensors in combination with AI are enablers for advanced process control. With state-of-the-art technologies it is possible (after a lot of training) to determine whether a product meets specifications. However, using these measurements for control is a totally different target. Three types of challenges can be identified:

- New sensors for NDT (and improved/new measurements)
- Reduce the training effort required to mature AI or improve the reusability of trained AI (How to deal with n=1?)
- Use heterogenic data sets from different type of (smart) sensors (incl. vision, sound, etc.) for process control

One challenge is to predicting the reliability of a complex manufacturing system by considering the challenge of anticipating unknown faults when hundreds to thousands of sub-systems or components interact.

Related Research & Innovation Objectives

- This R&I Objective supports the R&I Objective 1.2 'Scalable, reconfigurable and flexible first-time right manufacturing', but has also a long-term potential to be further developed and advanced under the whole program.
- R&I Objective 1.1 'Data highways and data spaces in support of smart and real-time connected factories in dynamic and robust value networks': A holistic approach

linking simulation, online process control and quality assessment should be considered.

- This R&I Objective is of strategic importance for the affordable and competitive production of new, sustainable and complex products. It therefore also contributes to the Specific Objective 2 'Circular products & Climate-neutral manufacturing'.

Key Technologies and enablers

- Smart mechatronic systems, devices and components
  - In-situ online inspection, including the application of machine learning algorithms using data sets obtained from in-process sensors to deliver near real-time advance process control and avoid end-of-process scrap.
  - Innovative sensors, sensor materials and innovative inception methods (machine vision in combination with AI), including secure wireless sensors (image-based and non-image based) with embedded/edge learning functions for predictive quality and maintenance. Identification of maximum thresholds for deviations. Automation for closed loop manufacturing,
  - Diagnostics and detection of anomalies in production lines and processes.
    - Non-invasive diagnostic systems (that require zero or only minor modifications of control software and hardware of production lines), based on already available standard signals and adaptable algorithms.
    - System diagnostics of production lines and processes, controlled by closed loops
    - Fast-NDT (e.g. Terahertz technologies and 5-axis control)

- Simulation and modelling, digital twins
  - Digital twin concepts covering design/material/technology for predictive quality during the production process.
  - Integrated manufacturing process models for total process analysis (across multiple processes) and subsequent optimisation. The process models must also link to business models to enable accurate consideration of factors such as cost and resource availability.
  - Model-based systems engineering (MBSE) for manufacturing; Integrate requirements with (parametric) models to enable rapid changes to manufacturing equipment and production lines (e.g. reconfigurations for personalized products, smaller batch sizes, smaller impact of changes).

- Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing
  - Machine learning (ML) solutions leveraging on previous experiences including both supervised and unsupervised solutions. Reinforcement learning based solutions for process autonomy towards zero-defect and zero-downtime.

    - Flexible data acquisition platforms capable of ingesting data from a wide range of industrial sensors including: analog (mV, current loop), digital (e.g. UART, HART, ModBus, RS-483)
    - "Virtual sensors", camera-based systems, and state of the art Internet of Things devices.
    - Self-configuration systems for process/manufacturing control. To reduce the effort of system deployment and configuration by increasing to the greatest possible degree autonomy in network formation, sensor discovery and the incorporation of process meta data.
- Standards and standardization
    - Quality standards
    - Interoperability is essential to interact with manufacturing equipment in both directions. Smart information flow: right information, at the right time, at the right place, in the right format.....
    - Integration of existing and legacy systems into a common platform to merge data into a unified standards-compliant data stream.
- Skills
    - One of the main challenges is managing complexity.

Additional observations and boundary conditions

- A major challenge is the adaptation of existing production systems and tools to meet the increasing demands of higher productivity and quality. Development and accessibility of cost-effective solutions is a major constraint. Not only in terms of cost of the solutions, but also agility of implementation.

2.1.4 R&I Objective 1.4: Artificial intelligence for productive, excellent, robust and agile manufacturing chains - Predictive manufacturing capabilities & logistics of the future

General objectives and scope

By leveraging its advantage of having excellent and worldwide competitive manufacturing industries as well as a growing academic AI community, Europe can gain a strong position in the AI-race specifically in the manufacturing sector.

Made in Europe will drive research in AI for manufacturing that is geared towards concrete applications based on context-dependent data collection, and assurance of data quality. More specifically capabilities shall be developed for AI based prediction, analysis allowing fast production line reconfiguration planning to react on customization and supply chain instabilities planning as well as context creation and interpretation with built-in robustness for the realities of a heterogeneous manufacturing ecosystem. Artificial intelligence is a core element of the Industry 4.0 revolution and is not limited to use cases from the shop floor. AI algorithms can also be used to optimize manufacturing supply chains, helping companies anticipate market changes. This gives management a huge advantage, moving from a reactionary/response mindset, to a strategic one.

Use of AI in manufacturing processes will have to meet the highest standards with regards to data protection, safety, reliability, quality and precision. AI algorithm robustness, as a combination of explainability and repeatability (certifiable AI), is one of the main challenges

Already today we need simplified AI tool sets for use in manufacturing environment that can be configured without highly skilled personnel (cookbook approach). Effective implementation of AI solution in brownfield logistic processes should facilitate a phased implementation that is planned in a holistic way.

The investment in AI technology knowledge/skillset today is huge. Also training AI algorithm requires much datasets which in manufacturing environment are not always easy to fill. Therefore, the relation between investment and improved manufacturing performance is not optimal and has to improve such that it becomes applicable for lower volume producing SMEs

Embedding AI in products has a sensible pay-back as each product is improved. However AI in manufacturing it is often used for fault detection, in well controlled manufacturing applications that are almost zero-defect (defects occurring a few times a year). Advanced pattern recognition to detect out-of-bound situations requires huge amount of training associated to costs that SMEs do not recover easily.

On the one hand, simple cookbook approaches are required, usable also in SME environments. On the other hand, advanced AI approached are required where blackbox models (in/output based models) are combined with pre-existing (white box) models in which all know information is incorporated. This means, making a simple physical/mathematical model (the digital twin model of products and manufacturing equipment, often already available) and use AI to tune the parameters such that training the AI algorithm can be minimal.

Relation to other Research & Innovation Objectives

- R&I Objective 1.4 is required to support and enable the R&I Objective 1.3**: 'Scalable, reconfigurable and flexible first-time right manufacturing'**, but has also a long-term potential to be further developed and advanced under the whole program.
- To make AI for manufacturing operations accessible there is also a need to connect with technologies for easing the context-based human understanding and interpretation of AI predictions and recommendations. This aspect is closely linked to the R&I Objective 4.2 **'Advanced human-device interaction'**. Together this will also be strongly interconnected with R&I Objective 4.1 **'Digital platforms and engineering tools supporting creativity and productivity of research & development processes'** to enable enhanced productivity and creativity.

Key Technologies and enablers

- Analytical services for the identification of patterns related to defaults or disturbances in the production process. This may translate to the identification of process design flaws, maintenance issues, root-cause analysis, early alarms, and mismatches between process design and execution. Machine learning for (multivariate and context-dependent) anomaly detection and drift detection. machine-generated data.
- Configuration control methodologies that can cope with the complexity, dynamic nature, self-learning and local vs holistic application of AI solutions.
- Data fusion approaches and methodologies for multi-source heterogeneous data. Data can come from a simulation or from real manufacturing data.
- Autonomous approaches to move from big data to relevant data.
- Emerging fields such as artificial immune systems or 'biologicalisation'.
- Data governance approaches for ensuring the reliability, availability and quality of data
- Standards and standardization for AI usage in a production environment. Efficient and effective use of ontologies for the digital integration of the value chain (data)
- Upskilling.

2.1.5 R&I Objective 1.5: Advanced manufacturing processes for smart and complex products

General objectives and scope

Products are becoming increasingly complex due to added functionalities or improved performance requests. As a result, there is a need to adopt new designs or advanced (multi) materials, decrease/enlarge the size of products or integrate micro-features or electronics in order to keep the outstanding quality of European products and ensure the leadership of the manufacturing sector.

Competitiveness, sustainability and varying demand need to be considered together. New solutions will not only support part complexity and product smartness but will also enable the production of sustainable products enabling durability, energy-saving and the replacement of scarce or hazardous materials. The impact of manufacturing on climate-neutrality across sectors (power generation, mobility, agriculture, clean tech, health…) is key.

Made in Europe will contribute with advanced manufacturing processes for new smart and complex products and solutions. *Made in Europe* will enhance parallel product and manufacturing engineering and the design for end-of-life/re-use/recycling which contributes to sustainable products, services and manufacturing networks.

Relation to other Research & Innovation Objectives

- R&I Objective 2.3: **'Manufacturing with new and substitute materials'** and R&I Objective 2.2: **'De-manufacturing, re-manufacturing and recycling technologies for circular economy'**. The expected product innovations towards Climate Neutrality need parallel investment in research and technology maturation at process level. This is an area where Europe is very well positioned, and we need to take larger innovative steps to progress in this area. Here, full industrial process chains (e.g. combining additive and subtractive manufacturing processes) need to be developed for specific application areas.
- There should be a complementarity with R&I Objective 1.2 **'High precision manufacturing for miniaturisation and functional Integration'** since, sometimes, complex products are associated to very small products. In R&I 1.2 the focus is on functionalisation (which includes size). Here the focus is on complexity due to innovative materials, design, new processes/chains for increased sustainability and agility.

Key Technologies and enablers

- Advanced and environmentally sustainable smart material and product processing technologies, and process chains

- Microelectronics, printed electronics and enabling nanotechnologies are highly relevant for smart products. There is a difference between smart products by means of (1) an embedded sensor or (2) a manufacturing process (ex. printed electronics). In both cases the result is a smart product, but manufacturing technologies are just involved in the second case and this should be covered by this R&I Objective.
- New additive manufacturing processes are also important for smart and complex products manufacturing. Ad-hoc technological manufacturing combinations and new materials are will disrupt and stimulate the area of manufacturing of smart/complex products, for example hybrid technologies such as those used in plastronics, combining printed electronics and plastic processing. Testing and quality control of such complex products are also needed.

- Smart mechatronic systems, devices and components
  - Highly automated manufacturing and process control for complex parts and multi material parts.
  - Novel inline quality measurement technologies (vision vs CAD, surface appearance, material properties), material identification/characterisation
  - Predictive quality and maintenance are key to ensure manufacturing quality.
- Digital twins
  - Understand, model and optimise the full chain of process stages.
- Standards and standardization
  - Standards and product certification for complex and custom products.
- Skills
  - Re-skilling and upskilling.

Additional observations, boundary conditions and initiatives

- Pilot lines are relevant in this area, in order to maximise impact at industrial level.

2.1.6 R&I Objective 1.6 High precision manufacturing for miniaturisation and functional Integration

General objectives and scope

Products are increasingly complex with increasing amount of electronics or micro-features and advanced (multi-)materials. Products are also becoming smarter, stronger, lighter and more miniaturised and functionally integrated whilst remaining safe and secure. Completely new solutions will be introduced when designing future **sustainable products** enabling durability, energy-saving and the replacement of scarce or hazardous materials.

Making components smaller and smaller by integrating functions in surfaces and in concentrated spaces is a cross-cutting enabler for a broad spectrum of applications. For example, high precision additive manufacturing with multifunctional additive materials to manufacture critical implants, medical phantoms for pre-surgery studies and other medical devices. The ability to customise and to integrate advanced functions will contribute to the competitiveness of European manufacturing companies in the globalised market.

Manufacturing system capabilities need to follow product and material roadmaps to enable the viable and sustainable manufacturing of these high-tech products. Integration of more and more features in devices reduces the overall number of products and enables the decoupling of resource use and added value.

Related Research & Innovation Objectives

- R&I Objective 1.5 **'Advanced manufacturing processes for smart and complex products'**
- R&I Objective 2.3 **'Manufacturing with new and substitute materials'**
- R&I Objective 2.2 **'De-manufacturing, re-manufacturing and recycling technologies for circular economy'**
- R&I Objective 2.4 **'Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks'.** Functional integration has to start from the design. Thus, progress on design and engineering tools supporting functional thinking and integration from the beginning shall be fostered in *Made in Europe* .

Key Technologies and enablers

Multiple technologies are needed, mainly the microelectronic and incumbent nanotechnologies in combination with mature manufacturing processes are essential for a proper functional integration and miniaturisation to advance into disruptive products and technologies.

- Advanced smart material and product processing technologies, and process chains
  - New and improved micro- and nanomanufacturing processes which are precise, repeatable, fast and easily scaled up.
  - New, improved and industrially scalable processes for micro- and nanoscale modification of materials, including laser processing and texturing, chemical processes (implantation, coating) to achieve miniaturisation of devices with added value properties (optical, microfluidics, mechanical, electrical…)
  - Functional integration of plastics/composites and electronics thanks to hybrid processes combinations: laser, ultrasounds, microwaves, additive manufacturing and joining of multimaterials, 3D-MID, in-mould electronics, overmoulding or electro-spinning. 4D printing for increased surface functionality and time-based functionality
- Smart mechatronic systems, devices and components
  - Embedded sensors for in-process and/or in-service monitoring.
  - Further integration of physical processes with digital technologies in-situ inspection methods.
- Edge computing: smart devices with embedded AI, federated machine learning.
- Simulation and modelling, digital twins
  - A holistic approach linking simulation, online process control and quality assessment.

Additional observations, boundary conditions

- There is a trade-off between functional integration and serviceability. Another trade-off is increased cost.
- It is essential to distinguish between integration in costly, long-life (20+-year) and shorter-life products. During their lifetime, long-life products need to be recycled once whereas short-life products lead to high recycling volumes in the same period. Zero defect manufacturing, without maintenance of the integrated components, is needed for integration in costly long-life products.

2.2 Research & Innovation Objectives under Specific Objective 2: 'Circular products & Climate-neutral manufacturing'

This Specific Objective includes the following Research & Innovation Objectives:

- **R&I Objective 2.1: Ultra-efficient, low energy and carbon manufacturing**
- **R&I Objective 2.2: De-manufacturing, re-manufacturing and recycling technologies for circular economy**
- **R&I Objective 2.3: Manufacturing with new and substitute materials**
- **R&I Objective 2.4: Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks**
- **R&I Objective 2.5: Digital platforms and data management for circular product and production-system life cycles**

Figure 7: Research & Innovation Objectives allocated to 'Circular products & Climate-neutral manufacturing'

2.2.1 R&I Objective 2.1: Ultra-efficient, low energy and carbon manufacturing

General objectives and scope

European manufacturing processes, production lines and factories must become more energy and resource-efficient (including water consumption), aiming at a zero-emission, zero-waste industrial activity that does neither deplete natural resources nor deteriorate living conditions on earth.

Made in Europe aims at ultra-efficient, low energy, circular and carbon-neutral manufacturing. *Made in Europe* will exploit the possibilities offered by advanced materials, digital technologies and manufacturing technologies to achieve a considerable reduction of the ecological impact and CO2-emissions.

Related Research & Innovation Objectives

- **R&I Objective 2.2 'De-manufacturing, re-manufacturing and recycling technologies for circular economy'**
- **R&I Objective 2.3 'Manufacturing with new and substitute materials'**
- **R&I Objective 3.2 'Manufacturing processes and approaches near to customers or consumers (including urban manufacturing)'**

Key Technologies and enablers

- Advanced smart material and product processing technologies and process chains
    - Innovative manufacturing processes for smart and carbon neutral materials in manufacturing. E.g. newly developed bioplastics which are carbon-positive require manufacturing processes to be tuned for its proper industrial processing.
    - Process chains (could include renewable energy integration and waste material/energy recuperation). This point can also be associated to new business and organisational approaches.
    - Hybridization of technologies - renewable energies integration, including the incorporation of energy storage, linked or focused on improving energy efficiency and the selection / validation / optimization of technologies.
    - CCUS (Carbon capture, utilisation and storage), Industrial Symbiosis, decarbonising of energy intensive process, clean energy production
- Smart mechatronic systems, devices and components
    - Renewable energy generation, energy storage and energy harvesting/recovery can contribute to reducing energy consumption and accelerate the transition towards a carbon-efficient economy.
- Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing
    - Prediction and optimised planning of energy consumption, synchronisation of energy demand with fluctuating energy supply
    - Resource and energy efficient production and logistics equipment, production planning and control

- Simulation and modelling, digital twins
    - PLM for Collaborative Manufacturing, need for systemic analysis of problems across industrial value chain.
    - The issue of decarbonization of the industry, particularly under the development of measurement / traceability / modelling / simulation technologies for the carbon footprint in manufacturing processes and supply chains. This could be summed up under the term "Carbon Twin".
    - New tools and methodologies should be developed to allow companies (both large and SMEs) to assess their environmental footprint and to calculate their individual contribution to the overall product environmental impact.
- New business and new organisational approaches
    - Incl. Assessment methodologies for realistic planning and follow-up of targets, from low-carbon dioxide to carbon-neutral
    - Integration of renewables, waste energy/material valorisation and industrial symbiosis concepts

Additional observations, boundary conditions

- More insight into the economic drivers of the implementation of new technologies and approaches in this area is required. Rising CO2 costs would make recycling more attractive, but servitisation (for instance associated to repair and maintenance) as business model too.

2.2.2 R&I Objective 2.2: De-manufacturing, re-manufacturing and recycling technologies for circular economy

General objectives and scope

Manufacturing is the linchpin for circularity, because enables regaining and upgrading of product functions material efficiency, the use of secondary materials, intelligent, lightweight products and energy-efficient processes.

As the biggest producer of production systems in the world, Europe needs to become the worldwide leader in the new technologies and systems for de-manufacturing, re-manufacturing, and recycling in order to maintain its strong positioning and to propose its perspective on environment preservation.

With higher expected CO2 prices and scarcity of key materials, the economics of manufacturing and products use and re-use will change. This will have an impact on manufacturing technologies and will require **new and different manufacturing equipment**. Hence, *Made in Europe* will develop advanced de-manufacturing, re-manufacturing and recycling technologies and solutions for a manufacturer-centric circular economy targeting manufacturing of products with new and substitute materials as well as embedding components designed for multiple use-cycles through remanufacturing for function restore and upgrade.

One cannot remanufacture etc. without a deep knowledge of manufacturing and production. An integrated approach to circularity will open a new era where product usage can be seen as responsible of wear and function degradation while remanufacturing can be seen a “purification” step to bring back the products to their original or even improved state.

Resource-efficient or circular approach necessitates the understanding of products and material flows and cooperation among organisations along the life-cycle and across sectors. Since most of the value of a product resides in its functions, the preservation, regaining and upgrade of product functions is the key to make circular economy profitable and therefore viable. This will require appropriate metrics and parameters which allow optimisation along the life-cycle.

Circular-by-design approaches needs to be applied including virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and value chains.

Related Research & Innovation Objectives

- R&I Objective 1.3 **‘Scalable, reconfigurable and flexible first-time right manufacturing’**: The introduction of advanced processes for repairing parts, reuse components as well as assets for improving efficiency, can be also reached by acting on flexibility, through easy reconfiguration of production equipment.
- R&I Objective 2.3 **‘Manufacturing with new and substitute materials’**
- R&I Objective 2.4 **‘Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks’**

- R&I Objective 2.5 **'Digital platforms and data management for circular product and production-systems life-cycles'**
- R&I Objective 3.1 **'Collaborative product-service engineering for costumer driven manufacturing value networks'**: Extending the service lifetime of products is an essential mechanism towards carbon and emissions neutrality. For instance: Remanufacturing and repair of automotive parts, particularly for new powertrains.

Key Technologies and enablers

- Advanced and smart processing technologies and process chains (post usage inspection, disassembly, cleaning, additive, joining, assembly, shaping, structuring, surface tailoring, etc.) whilst ensuring appropriate quality, scalability, affordability
  - De-manufacturing and remanufacturing systems should be integrated with manufacturing systems in order to guarantee synergies and avoid duplication of processes. New approaches are required to integrate the production of remanufactured products together with the manufacturing of new products while preserving quality and guaranteeing traceability of the different flows.
  - New technologies to guarantee the cleaning of disassembled parts while preserving the environment are needed.
  - Green chemical and thermal recycling technologies
  - Additive manufacturing technologies for repair and extension of the product's lifetime
  - De-manufacturing, remanufacturing and repair of plastics and composites: advanced thermoplastics materials and associated repair processes, delamination concepts/technologies for composite/multilayer materials, chemical, mechanical, laser etc.
- Smart mechatronic systems, devices and components
  - Inspection technologies for assessing the characteristics of the product during and after its usage. New or enhanced types of sensors as well as new methodologies (including those related to AI and data fusion) are required in order to interpret data from multiple sensors used on the same product.
  - New technologies and systems to identify and sort parts coming from different generations of products and assess their health state (e.g. functional tests on key components).
- Intelligent and autonomous handling, robotics, assembly and logistic technologies
  - AI and robotic sorting technologies. The challenge is to automate the process of assessing the state of, disassembly and sorting of used products, achieving the same level of efficiency as in production.
  - New technologies for the identification and mechanical separation of shredded materials including metals and plastics
  - Waste management facilities, scalable sorting technologies for sorting, recycling of plastics products:
    - Innovative compositional sorting (such as near infrared) technologies
    - Digital watermarking of product for separation during recycling

        - Decontamination technologies for product with food contact or medical applications (advanced super critical CO_2-based decontamination)
        - recovering of scarce and strategic materials
    - Mechanical recycling technologies through morphology controlled blends of materials
    - Development of renewable electricity driven recycling technologies. Industrial application of electricity driven technologies.
- Simulation and modelling, digital twins
    - Eco-design, design for dis-assembly, for de-manufacturing, see also R&I Objective 2.4 'Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks'
- Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing
    - Need for systemic analysis of challenges across industrial value chains.
    - Life cycle analysis tools, product health monitoring sensors.
    - New approaches to forecast the flow of product (times, quantity, predicted state) from the market after their use .
    - See R&I Objective 2.5: Digital platforms and data management for circular product and production-systems life-cycles.
- New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, liability/ accountability.
    - Business models should support the complete life cycle
    - Product functions which cannot be used anymore in the original sector may be used in other sectors (e.g. remanufactured batteries which are not efficient enough for transport application may be used in static applications)
    - Industrially symbiotic models to be extended across value chains: one industry's waste/by product is another industry's raw material. Manufacturing companies will get more integrated in local, circular value chains which stimulate exchanges of resources (re-use, byproduct material, co-products, recycled material, energy,...) between companies according to the principle of the industrial and territorial ecology.
    - Manufacturing routes could be critical to work for circular economy in a very efficient way easy to easily uptake by a high number of industrial companies in Europe
- Standards and standardization
    - E.g. work at ISO level on standards for circular economy.

Additional observations, boundary conditions

- De-manufacturing and remanufacturing of production systems is highly relevant. Manufacturing systems are themselves highly complex and in continuous evolution. The ability to regain or even upgrade the functions of existing production systems is a key factor to guarantee more efficient and up to date European production facilities.

- The usage of product(s) massive waste flow(s) for the re-manufacturing and de-manufacturing post and new production, raises the linear economic approach from its current state while creating more sustainable manufacturing.
- The shift of paradigm is huge. Activities should not be limited to reuse of components and/or materials to produce the same thing. Otherwise the scope is very reduced and often not realistic from an economic viewpoint.
- There are already examples of how a circular approach can be profitable and therefore desirable for companies. This concept needs to be expanded by overcoming the barriers that hinder this evolution.
- Manufacturers are at the centre of the circular approach since they know all the details of their product and of the processes used; through the relation with their customers they can also acquire information on the product usage. All this knowledge plays a key role in product de-manufacturing, remanufacturing and materials recycling.

2.2.3 R&I Objective 2.3: Manufacturing with new and substitute materials

General objectives and scope

New materials that are not scarce (preferably renewable/recyclable) provide new and substitute materials for actual and future products. E.g. The need to reach the goals of the European Green Deal and the related CO2 regulations implies the weight reduction of vehicles in all transport sectors.

At material level this implies reducing thicknesses, increasing material properties, applying industrially scalable local tailoring of properties and exploring new material combinations during the assembly processes. Manufacturing processes need to be developed and upscaled for a controlled and reliable production of products composed of such materials. Transformation processes need to be developed for or adapted to the new materials, including quality controls. In addition new value chains will need to be developed considering end-of-life treatment of such new products and materials.

New or substitute materials include multi-functional materials, meta materials, nano-technologies, recycled materials and scrap use as raw material sources to manufacture high performance composite, metallic products or bio based and recycled materials and fibers for green products and textiles, the use of new biodegradable and green materials in additive manufacturing, etc.

It is essential that such materials contribute to improved sustainability for instance leading to weight reduction for energy and material efficiency, recyclability through easy dismantling and sorting, performance and health monitoring capabilities etc.. In addition, these new materials bring improved product functionalities while production costs should be maintained at competitive levels. This includes materials which are not 'brand new', but have not yet been applied to certain sectors due to lack of upscaled facilities, rules and regulations etc.

Related Research & Innovation Objectives

- R&I Objective 2.2 **'De-manufacturing, re-manufacturing and recycling technologies for circular economy'**
- R&I Objective 4.1 **'Digital platforms and engineering tools supporting creativity and productivity of manufacturing development'**

Key Technologies and enablers

- Advanced smart material and product processing technologies and process chains
    - Joining technologies of multi-materials.

E.g.: Friction Stir Welding (FSW), initially developed for the joining of Al-alloys, is already extended to similar and dissimilar metallic joining (e.g. aluminium/titanium, aluminium/magnesium, among others). However, only recently research oriented to new dissimilar material joint solutions, such as (dissimilar) thermoplastic/thermoplastic polymer joints (e.g. PP/PE), thermoplastic polymer/metal joints, thermoplastic matrix composites/metal joints.

  - Additive Manufacturing technologies
  - Composite manufacturing technologies
  - Coating technologies
  - Scalable processing routes able to achieve local tailoring of properties demonstrating ease of recycling over multi-component assemblies with equivalent functionalities.
- Smart mechatronic systems, devices and components
  - Adapted characterisation methods and quality controls for the new materials in different formats and for the obtained products
- Simulation and modelling, digital twins
  - E.g. Application of topology optimisation-aided design to conventional manufacturing techniques, including multi-material assemblies or tailoring of properties.
- New business and new organisational approaches, including links with regulatory aspects
  - New value chains will need to be developed considering end-of-life treatment of such new products and materials.
- Standards and standardization
  - Validation and standardisation of bio-based and recycled materials on a European scale, certification schemes

Additional observations, boundary conditions

- Eco-design and critical materials analysis (LCA). Testing, Certification and Quality assessment (also remotely) of new materials is challenge.

2.2.4 R&I Objective 2.4: Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks

General objectives and scope

The increasing complexity and innovation rate of products and production technologies, the increased customisation and growing sustainability requirements require that **product design and engineering are carried out in parallel with manufacturing system engineering and configuration**. Manufacturing is the key enabler for producing the climate-neutral products across all sectors, not only from the circular economy perspective (e.g. through design for recycling) but also from the perspective of the energy and resource consumption of these products during the use phase.

New manufacturing capabilities, materials and processes open up new possibilities for integrated functional designs. These capabilities come with potential complexity that can only be mastered by innovative design and engineering tools fostering creativity and increasing productivity along the product and manufacturing development.

Related Research & Innovation Objectives

- This R&I objective is key to Specific objective 1 **'Excellent, responsive and smart factories & supply chains'**. Product development and industrialisation is focused on quality, performance and costs; production line OEE (Overall Equipment Edfficiency) and ZDM (Zero-Defect Manufacturing). The time to start new production and the optimisation calibration and configuration of process set-up is essential to be competitive even if the factory has invested in advanced technologies and skilled people.
- **R&I Objective 2.5 'Digital platforms and data management for circular product and production-systems life cycles**
- **R&I Objective 3.1 'Collaborative product-service engineering for costumer driven manufacturing value networks driven manufacturing value networks**
- **R&I Objective 4.1 'Digital platforms and engineering tools supporting creativity and productivity of research &development processes'**

Key Technologies and enablers

- Advanced smart material and product processing technologies, and process chains
  - The design chain is mandatory. The material and the product design affect the production management and vice versa - the optimisation of design and manufacturing process have to work in a collaborative way for traditional processes as well as advanced ones (e.g. Design for Additive Manufacturing).
- Simulation and modelling, digital twins, digital shadows, virtual engineering and manufacturing.
  - Digital twins represent a great opportunity to continuously improve production quality and performance, while offering a precious virtual test bed for investigating defects and malfunctions, but must be continuously and consistently be synchronised with factory operations and digital representations of parts and production processes. Real-time monitoring the manufacturing shop floor through the digital twin and using it as a test bed for experimenting new designs and processed for complex aerospace operations is a necessity in the industry.
  - Methods for integrating life cycle considerations such as maintenance, repair, spares, recycling, and disposal in cost/affordability models.
- Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing

  - Industry requires flexible and robust platforms for data acquisition, data analytics, artificial intelligence based on standards and appropriated protocols. The integration of right engineering tools, the digital management platform and the adoption of digital twin approach should be customer-oriented. (See R&I Objective 2.5 'Digital platforms and data management for circular product and production-systems life-cycles' and R&I Objective 3.1 'Collaborative product-service engineering for costumer driven manufacturing value networks driven manufacturing value networks')
  - Tools for keeping the data organised, without out-of-sync duplications, and with clear semantics and readily understandable meaning. Digital models of the parts and the production processes are an opportunity to provide context to the data, but at the same time represent a challenge to maintain consistency and link with the data and across the manufacturing and business layers.
- New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability
  - Cross-sectorial organisational innovation and collaboration to optimise life cycle cost and environmental impact, including the material flows and resource efficiency.
- Standards and standardization
  - Ontologies for end-to-end lifecycle integration
- Skills
  - Tools such as advanced modelling tools for 3D and 4D objects, functional integration, multi and mixed material parts and complex organic shapes, alongside with the corresponding simulation tools and optimization methods that integrate human creativity into rapid automated computing in an augmented intelligence way.

Additional observations, boundary conditions

- Consider the difference in product lifetime. E.g. How to mass integrate digital tools with a update or replacement cycle of few years into an product with a 50 year life cycle?

2.2.5 R&I Objective 2.5: Digital platforms and data management for circular product and production-system life cycles

General objectives and scope

The manufacturing industry is undergoing a fundamental transformation towards the increased sustainability of products, processes and productions systems, based on the effective implementation of circular economy principles and options for high value-added product materials and function re-use along multiple product use-cycles.

However, current limitations exist that bound the scale and impacts of this ongoing transition. Among these, product data and knowledge are not exchanged among manufacturers and de- and remanufacturers, as well as among sectors leading to unlocked cross-sectorial material and function re-use opportunities. Furthermore, the lack of certification protocols for secure re-used materials and components transfer among sectors limit the level of confidence (‘accountable manufacturing’) towards this circular model.

New concepts of Circular Economy digital platforms will overcome the current information asymmetry among value-chain stakeholders, in order to unlock new circular business models based on the data-enhanced recovery and re-use of functions and materials from high value-added post-use products with a cross-sectorial approach. Such multi-sided digital platforms should provide modular, scalable, and open services to various stakeholders in the value-chain in different sectors and should support improved and secure traceability of materials and components’ key characteristics along the different stages of the circular value-chains of the future.

Related Research & Innovation Objectives

- R&I Objective 1.1 **‘Data ‘highways’ and data spaces in support of smart and real-time connected factories in dynamic and robust value networks’**

  A data space for accountable manufacturing that will allow exchanging Information and obtaining ‘the full picture’. A multi-user data space platform, using decarbonization and circular production as a driver.

- R&I Objective 3.3 **‘Transparency, trust and data & IP integrity, open systems and cyber security and along the product and manufacturing life-cycle’**

Key Technologies and enablers

- New dimensions of data and information systems for management of energy systems will be required
- Interoperable hybrid IoT architectures with big (small) data analytics capabilities and semantics support for data exchange and knowledge generation focusing on circular production and economy.

- New business and new organisational approaches, including links with regulatory aspects : 'Accountable manufacturing'
    - Engineer and master an expanded concept of products, services and processes
    - Understand better the role, the opportunities and impact of manufacturing
    - Improve metrics and cross-sector/cross-disciplinary information exchange
- Standards and standardization
    - Standards, certification and legislation for cross-boundary data and recycling management.
    - See R&I Objective 3.3: Transparency, trust and data & IP integrity, open systems and cyber security and along the product and manufacturing life-cycle
- Skills

Additional observations, boundary conditions and initiatives

- Actions should aim at maximising impact at industrial level.
- There is a need to consider how to reuse hardware and software in industrial systems. Not only "Digital Twins" are important, but also "Digital Threads", which are actually more challenging. (Digital Threads = a holistic view of an asset's data across its product lifecycle).
- Data (and availability of quality data). De-manufacturing and recycling are defined technologies. However, the experience has demonstrated that reliability of Life Cycle Analysis is strongly depending on the quality of the data obtained. Strong discrepancies might appear in LCAs. Alternative/complementary approaches are Environmental Technology Verification.

2.3 Research & Innovation Objectives under Specific Objective 'New integrated business, product-service and production approaches; new use models'

This Specific Objective includes the following Research & Innovation Objectives:

- **R&I Objective 3.1: Collaborative product-service engineering for costumer driven manufacturing value networks driven manufacturing value networks**
- **R&I Objective 3.2: Manufacturing processes and approaches near to customers or consumers (including urban manufacturing)**
- **R&I Objective 3.3: Transparency, trust and data & IP integrity, open systems and cybersecurity along the product and manufacturing life-cycle**

Figure 8: Research & Innovation Objectives allocated to 'New integrated business, product-service and production approaches; new use models'

2.3.1 R&I Objective 3.1: Collaborative product-service engineering for costumer driven manufacturing value networks driven manufacturing value networks

General objectives and scope

Manufacturing continues to be transformed by new technologies, new business models and an increasing complexity in consumer expectations on product connectivity, sustainability and convenience. The services component of the revenues generated by these products, in particular B2B products, continues to increase. The opportunity to link this trend with considerations relating to sustainability and the circular economy , represents a significant opportunity for European manufacturing.

The interaction of value network players through these services can lead to vertical integration in manufacturing (among OEMs, Tier1 to Tierx suppliers, where suppliers tend to provide services (supporting product-design and manufacturing engineering). On the other hand, horizontal integration is also an ongoing trend where service development will increase (for instance in the transport sector, supplying mobility as a solution rather than the vehicle).

Made in Europe will **couple** more tightly the flexible design, manufacturing and (re-) configuration of products **with the services** associated to these products, through production and throughout their lifecycles.

Related Research & Innovation Objectives

The associated services have a direct connection to the creation of value, in particular associated to circular economy and sustainability (Specific Objective 2) and excellence and competitiveness (Specific Objective 1). In particular R&I Objectives 1.1 and 2.2, 2.4 are listed here to illustrate this direct relation.

- R&I Objective 1.1 **'Zero-defect and zero-down-time manufacturing, including predictive quality and non-destructive inspection methods'**
- R&I Objective 2.2 **'De-manufacturing, re-manufacturing and recycling technologies for circular economy'**
- R&I Objective 2.4 **'Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks'**
    - Associated to the anticipation of customised services along the life-cycle of products and production systems

Key Technologies and enablers

- Advanced smart material and product processing technologies, and process chains (additive manufacturing, joining, shaping, structuring, surface tailoring, etc.)
    - See also R&I Objective 1.5: Advanced manufacturing processes for smart and complex products. There is a tight interrelation between the manufacturing processes and their impact on the services along the product life-cycle (including re-use and remanufacturing).

- Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing
    - Data and associated analytics, leveraging the potential of Artificial Intelligence (AI), Internet of Things (IoT), mobile and ubiquitous ICT tools.
    - Connect different stakeholders of the value chain, from the material providers up to the end-users. A closed-loop digital pipeline connecting engineering, management, production and services for defining a more accurate manufacturing and service strategy.
- New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability
    - New business models and new digital services to improve opportunities for companies and support the return on investment (affordable solutions) of users, especially SMEs.
    - Human-driven innovation, co-creation, management of data for customer-driven manufacturing.
- Novel holistic approaches, leveraging the potential of Artificial Intelligence (AI), Internet of Things (IoT), mobile and ubiquitous ICT tools
- Standards and standardization
    - Interoperability is a key requirement. Data management system are collecting information from different customers. Getting the data automated way and removing manual operation for gathering data from various sources
- Skills
    - Link with R&I Objective 4.1 'Digital platforms and engineering tools supporting creativity and productivity of research &development processes'.

Additional observations, boundary conditions

- COVID-19 has demonstrated the need for innovative approaches to value creation such as remote maintenance, remote control of logistics, remote access to customers. The adaptation to new customer demands will require a collaborative product-service design.
- There is an opportunity to cross-fertilise using existing approaches across sectors, for instance considering the customer- oriented and personalised service cases from the medical devices sector.
- In the context of *Made in Europe*, the product-service approach is also applicable to cases were the 'product' is the manufacturing system (equipment or production line) and in that case there is a big link with the Specific Objectives 1 and 2.

2.3.2 *R&I Objective 3.2: Manufacturing processes and approaches near to customers or consumers (including urban manufacturing)*

General objectives and scope

In future, excellent and smart factories can fully offer and deploy their capabilities in **dynamic and sustainable manufacturing ecosystems** where digitalisation delivers new ways to interact with customers, consumers, and users. *Made in Europe* will contribute to making this a reality and will define approaches for implementing manufacturing processes that are closer to customers or consumers (urban manufacturing).

Personalisation and sustainability are driving forces to achieve a leading role in a fast-changing market. Keeping production **near to the customers** is pivotal to reduce dependency and fragility of external supply sources, maximising production resiliency and minimising environmental burden. The urban manufacturing concept, thought as a production scenario leveraging closeness to customer, customisation and sustainable, near zero emission production, should become the 2030 production standard.

The concept of near to customer manufacturing is also applicable in the B2B context. For instance, the production of spare parts for the repair of large, complex structures such as ships, offshore structures etc.

To make this vision a reality, manufacturers need to become more agile and flexible, introducing customer-oriented products and services, while measuring and capitalizing environmental intangibles. Leveraging on digital and distributed manufacturing, broad availability of product lifecycle data and an intensive use of human empowering automation solutions, manufacturing value networks can be reshaped towards collaborative, very short value chains and responsive production in constrained environments for customer-oriented products and services.

Related Research & Innovation Objectives

- R&I Objective 1.5 **'Advanced manufacturing processes for smart and complex products'**
- R&I Objective 2.2 **'De-manufacturing, re-manufacturing and recycling technologies for circular economy'**
- R&I Objective 4.1 **'Digital platforms and engineering tools supporting creativity and productivity of research & development processes'.**

Key Technologies and enablers

- Advanced smart material and product processing technologies, and process chains (additive manufacturing, joining, shaping, structuring, surface tailoring, etc.)

    - Additive Manufacturing is a key enabler of Urban Manufacturing, manufacturing on demand and at point of use.
    - Repairing techniques at the customer site - for instance using additive manufacturing - or remote support to repair (given the urgency of repairs and often quite high cost of spare parts to keep in inventory).
    - Adoption and up-scaling of fast prototyping technologies: Beyond additive manufacturing. Nano-scale 3D printing, beyond applications in medicine
- Smart mechatronic systems, devices and components
    - Collaborative robotics
- Deployment of digital platforms for data management and sharing
    - See also R&I Objective 4.1 'Digital platforms and engineering tools supporting creativity and productivity of research & development processes'
- New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability
    - E.g. to support close to customer (operator) increased maintenance, repair or overhaul for high value assets – reducing cost of ownership, creating new service support business models . Typical use cases pursue as primary requirement the responsibility and assessment of safety of repairs or manufacturing at the customer site.

Additional observations, boundary conditions

- Optimised logistics is an enabler as well. On the other hand, more resilient and robust value chains can be enabled by local manufacturing.
- Competition in the use of land between housing, office, industrial projects makes it difficult for manufacturing companies to relocate within the urban fabrics where land prices are very high. New innovative urban development models favouring a functional mix must be considered by town planners, land/real estate developers, and manufacturing companies to give place to a new form of urban manufacturing, denser, city friendly and more affordable, with special consideration to the re-use of old industrial buildings and brownfields.
- Acceptance by citizens to have industrial sites in their immediate living neighbourhood is also a requirement

2.3.3 R&I Objective 3.3: Transparency, trust and data & IP integrity, open systems and cybersecurity along the product and manufacturing life-cycle

General objectives and scope

While products become more and more customised, the **end-to-end integration of manufacturing networks** is important, including logistics, which is a critical factor for unleashing the potential of very flexible distributed production. *Made in Europe* will develop technologies and methods to enable dynamic and sustainable value networks by the continuous and secure integration of digital technologies (5G, distributed ledgers, AI, etc.) into legacy approaches, supporting hardware and software lifecycle optimisation of products and manufacturing systems. This will lead to transparency, trust, and data integrity along the manufacturing and product lifecycle.

Flexible and agile manufacturing, customer-driven, low-volume and demand-driven production are key priorities to reduce manufacturing lead time and costs. To achieve these objectives, highly automated customer and supply chain management is a critical ingredient that can only be realised with an adequate digital infrastructure.

Next to the importance of transparency, trust and data/IP integrity in the design and manufacturing part, the same will become importance during the product use and re-use/recycle phase. As material costs will increase due to CO2 avoidance costs or scarcity, reuse of materials will imply that products and their components are re-manufactured, re-used, re-furbished and re-cycled as much as possible. It is expected that more and more capital goods will be offered in a *servitisation business model* and consumer goods with a deposit representing the value of the material. Products with material passports and goods with unique digital twins that follow the usage of the products during their lifetime will require data spaces with the information of individual products.

Related Research & Innovation Objectives

- R&I Objective 1.6 **'Data 'highways' and data spaces in support of smart and real-time connected factories in dynamic and robust value networks'.**
- R&I Objective 2.5**: Digital platforms and data management for circular product and production-system life cycles**
- R&I Objective 1.4**: Artificial intelligence for productive, excellent, robust and agile manufacturing chains**

Key Technologies and enablers

- Digital Twins, digital threads
  - Digital twins build on top of multi-site, multi-administrative B2B domains (designer, manufacturer, maintainer, dismantler, ….) following different regulations and standards. However, digital Twins (of Things) are not enough to follow the whole life cycle, especially when human interactions play a key role in the process.
- Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing
  - Reference architectures for Data Sharing Spaces (IDSA), standard Data Models (RAMI Asset Administration Shell), distributed ledger technologies (Blockchain)
  - Smart self/supervised-learning data sniffing solutions to ensure data availability, reliability and quality
  - Full production traceability and full autonomous quality control based on AI solutions that leverage on equipment data and sensors (both real and virtual) are required to establish a trustful relationship among players of the production and product value chain. Transparent AI-based predictive quality ensures that manufacturers and customers are compliant with quality regulations and specifications.
- New servitisation business models and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability
  - The Green Deal and the circular economy will require a new level of accountability
  - Copyright/data ownership is needed for products and (autonomous) systems to safeguard IP. The AI algorithm could be owned by the manufacturer, the product by a leasing company, but the user generates the input/output which could be used to improve the AI algorithm. There is a need for legal agreements, preferably generic and not custom made in order to reduce costs.
  - Managing change control, review and approval of manufacturing within industries with high regulatory oversight.
  - Data governance approaches for ensuring the reliability, availability and quality of data.
  - Development of suitable labelling and communication methods for end users and citizens, so they can take responsible consumption decisions. (similar to the Energy Classes A+ A++…)
- Cyber security
  - Cyber-security requirements in industrial environments (industrial internet, operational technology (OT) environment are more strict than IT security due to the fact that malfunctioning of equipment can cause human injury.
  - New distributed data security models, performing research on innovative aspects regarding data integrity, confidentiality, privacy and non-repudiation.

- Cloud, edge, embedded secure processing and added value analysis
- A key requirement of such a digital infrastructure is the assurance of digital communications across factory boundaries, including access control, protection against cyber-attacks, data privacy and integrity, intellectual property protection, etc. Given the substantial use of legacy equipment, factories are more vulnerable to today's cyber-attacks than ever before.
- Validate and verify security functions in critical assets (e.g. SGX enclaves and their interfaces, IIoT security functions, NFV/SDN controllers, or cryptographic libraries). Develop and deploy solutions for detection of the most serious vulnerability classes in industrial software: Automated monitoring and extraction of dataflows to detect threats. Simulation of attacks in different network configurations.
- Approaches such as homomorphic encryption
- Distributed ledger technologies with unique product IDs.
- A unique, not easy to tamper or remove identifier/product-ID (beyond barcode and usable for distributed ledger/blockchain) that relate the product to its digital twin/thread.

- Standards and standardisation
  - Standard Data Models are required to follow the Product / Production lifecycle especially along some decades
  - The transition to Open systems and the use of standards will be increased.
  - Interoperability, building on ontologies for traceability over the value chain, integrating heterogenous data from different sources, to ensure conformance.
  - Appropriate metrics and parameters which allow understanding and optimisation between sectors, disciplines and along the life cycle.

Additional observations, boundary conditions and initiatives

- Example: The production of medical devices is strictly regulated and controlled by third-party quality assurance procedures (for instance, according to Council Directive 93/42/EEC); Manufacturers, for example, must certify the end-to-end production process going from raw material handling, over material shaping and processing, to product assembly. Enabling external audits to assess the quality and correctness of the production process requires full traceability of the production process. Achieving traceability implies that production companies not only have to monitor production assets (e.g. machines, robots, conveyor belts, pipes, drying units, etc), they also have to guarantee that the collected data from sensors, cameras or PLC controllers is genuine and cannot be tampered with.
- There is a need to deploy and further develop new technology enablers to large scale cross-domain experiments, building the EU Data Sharing Space for Manufacturing, valorising EU values and legislation in privacy / confidentiality preservation. Long life-time industries (machine tools, automotive, aeronautics, shipbuilding) will run their complex value chains and long-lasting lifecycles in a standard and trusted way. High-value high-margins industries (fashion, cosmetics, food) will provide consumers with

transparent and trusted chained data spaces, guaranteeing origin and provenance of materials & components

- Solutions need to bridge the gap with the factory floor, for instance by creating structured arrays of data from production process inputs and outputs and laying the foundation for the architecture of a connected factory in terms of requirements, best practices and data activation.

2.4 Research & Innovation Objectives under Specific Objective ‘Human-centered and human-driven manufacturing innovation’

This Specific Objective includes the following Research & Innovation Objectives:

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- **R&I Objective 4.1: Digital platforms and engineering tools supporting creativity and productivity of research &development** processes
- **R&I Objective 4.2: Advanced human-device interaction.**
- **R&I Objective 4.3: Human & technology complementarity and excellence in manufacturing**
- **R&I Objective 4.4: Manufacturing Innovation and change management**
- **R&I Objective 4.5: Technology validation and migration paths towards full industrial deployment of advanced manufacturing technologies by SMEs**

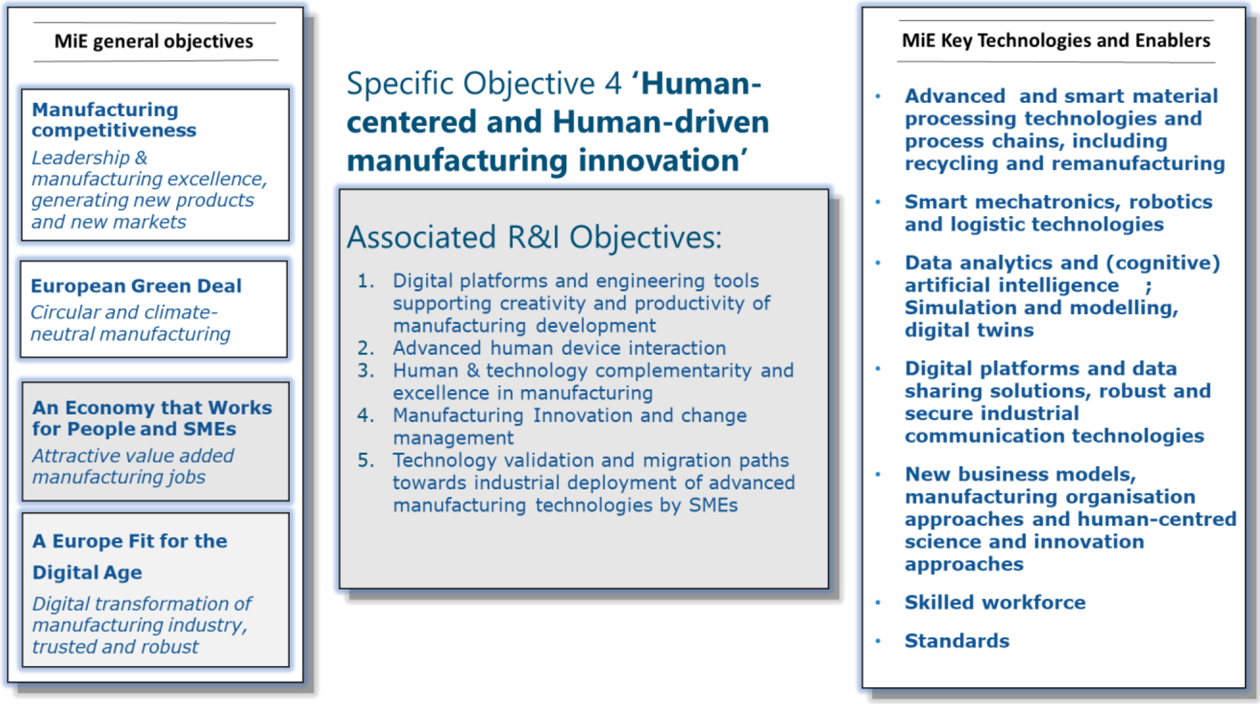

Figure 9: Research & Innovation Objectives allocated to 'Human-centred and human-driven manufacturing innovation'

2.4.1 R&I Objective 4.1: Digital platforms and engineering tools supporting creativity and productivity of research &development processes

General objectives and scope

Humans are at the core of the **innovation process**, increasingly supported by data analytics and decision support systems. Innovation is a process where different processes and disciplines (technological and non-technological) converge into concrete solutions and implementations. *Made in Europe* will develop new approaches and tools (including strategy management) that strengthen the capability of industrial actors to draw value from external sources of creativity, including start-up companies.

Design and development of advanced technologies will consider the **role of the workforce** at the earliest stages and will consider the available or required additional skills of the people involved. The full benefit of new tools based on advanced technologies can only be achieved by designing new work practices and by involving employees in the co-design. It is for instance of great importance to investigate how human knowledge and skills can complement Artificial Intelligence solutions and how smooth human-AI or human-robot interaction can take place. Tools and methodologies to ensure knowledge management and transfer are also of great importance .

Digitisation in Manufacturing Innovation suggest new processes and workflows (virtual and physical) that need to be designed and validated together with humans from the entire manufacturing life cycle starting from design and engineering covering production and comprising user experience with mass or customised products.

Creative processes should however not be dependent on digital platforms, but these will improve efficiency of creativity of engineers and designers, opening new room for innovation. These tools will support the adaption of skills to new job requirements, including technological and organisational changes.

Related Research & Innovation Objectives

- R&I Objective 2.4: **Virtual end-to-end life-cycle engineering and manufacturing from product to production lines, factories, and networks**
- R&I Objective 3.1: **Collaborative product-service engineering for costumer driven manufacturing value networks driven manufacturing value networks**

Key Technologies and enablers

- Simulation and modelling, digital twins
    - New manufacturing capabilities, materials and processes open up new possibilities for integrated functional designs. These capabilities come with potential complexity that can only be mastered by innovative design and engineering tools fostering creativity and increasing productivity along the product and manufacturing development. Tools such as advanced modelling

tools for 3D and 4D objects, functional integration, multi and mixed material parts and complex organic shapes, alongside with the corresponding simulation tools and optimization methods that integrate human creativity into rapid automated computing in an augmented intelligence way.
  - Advanced user interface technologies (mixed/augmented/virtual reality) for human centric workplaces and products.
  - Digital platform supporting MBSE (Multi-Body Systems Engineering) methodologies linking a wide variety of models and data into a holistic representation to support efficient and effective development, manufacturing and support.
  - Digital twin to support the digital customer journey and engineering services along the entire product life cycle
- Data analytics, artificial intelligence, machine learning and deployment of digital platforms for data management and sharing
  - Digital tools that can provide AI-driven guidance and recommendation to identify, recommend, and implement improvements along the production value-chain.
  - Concurrent engineering 4.0
- New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability
  - Incorporate new knowledge from workers into digital twins so knowledge can be shared (e.g. with the new workforce). However, the know-how of industrial workers must be protected from unauthorized use, especially by data and analytics companies.
- Skills
  - Supporting re- and up-skilling of manufacturing workforce
  - Enhance the engineering/design capabilities and efficiency of European innovators - engineers, designers, material scientist, entrepreneurs.
  - Improve the connection between research and universities and professional training and Vocational Education and Training (VET) centres.
  - reducing the skills and knowledge gap, easing the shortage of engineers and data scientists, increasing productivity of R&D&I
  - Low-barrier, cost-efficient tools

Additional observations, boundary conditions and initiatives

- A primary enabler and human-centred digital platform is already available in the pockets of most people: our mobile phones that are the natural drivers for innovation, communication, training, and remote control. Through mobile and personalised communication, a human-centered digital eco-system will evolve, providing the sources for many of the needs and impact described.

2.4.2 R&I Objective 4.2: Advanced human-device interaction.

General objectives and scope

The required perspective to the role of humans in manufacturing is a human-centred one, addressing the well-being, attractiveness, health and safety of the people at work at any level of all manufacturing phases (as opposed to a top-down or system/society-oriented approach)

The goal is to improve the awareness, preparedness, communication, resilience and safety of the worker, having both a positive impact on worker's wellbeing as well as on the performance of the manufacturing operations (mostly covered by the other Specific Objectives in this SRIA).

Human-device interaction and orchestration involves the interaction of the worker with other remote and on-site experts as well as smart production systems and tools. Solutions should support individual preferences, capabilities and state but also knowledge (e.g., human digital twin and knowledge management tools)

Both, changing value-creation processes and new "human augmenting" technologies will lead to **new job profiles** (e.g. "from operator to orchestrator" and aligned to the needs of new and advanced manufacturing technologies and processes) and require **new skills** as well as – in line with the ageing work force, the increasing digital skills and the accelerating transformation of work – **new ways of personalised learning** (on the job or modular approach to learning and training). Keeping in mind that "traditional" highly skill-full jobs will always be needed by industry and that there is also a greater shortage of this professional profiles).

Good work and attractive high-quality jobs in thereby highly successful manufacturing companies is the aspiration.

Related Research & Innovation Objectives

- R&I Objective 4.3 **'Human & technology complementarity and excellence in manufacturing'**
- R&I Objective 1.4 **'Artificial intelligence for productive, excellent, robust and agile manufacturing chains'**

Key Technologies and enablers

- Advanced smart material and product processing technologies (additive manufacturing, joining, shaping, structuring, surface tailoring, etc.)
    - Focus on health and safety characteristics
- Smart mechatronic systems, devices and components, intelligent and autonomous handling, robotics, assembly and logistic technologies
    - Multi-scale multi-level safety control associated to powerful analytics, adapting the machine/robot behaviour for smart and safe interaction

    - Real-time integration with manufacturing systems, locally and remotely
    - Detecting the present mode/state of the human, before delivering information, advice or requirements/orders. E.g., sensory input needs to detect if the human is in a stressed state and not receptive. A broad range of sensors are therefore important enablers.
    - Technologies easing the physical and mental burden, from exoskeletons and wearables to AI systems that help to analyse situations in dense operational environments (like automatic pilots in airplanes), especially for the ageing workforce in Europe
    - Multimodal, effective assistance interfaces, combining different modes (e.g. speech and image) simultaneously: I.e. development of flexible and situational formats and media that can be used and tolerated by humans and through which assistance can be offered effectively, efficiently and safely. Overall goal is the effective and adaptive interaction and communication between man and machine. Additionally, interfaces should be flexible and compatible with different end devices.
    - Mechanisms for instructions delivery to non-robot experts for failures recovery.
    - Different virtual interfaces for the same physical machine: Overlay of the real world with the virtual world, i.e. development of Extended Reality tools and interfaces for human interaction with machines, adapted and individually designed for the specific user and operator. Interacting with one/same machine, but doing different or the same things with it, but according to the specific virtual interface and user needs.
    - Assurance/increase of the Quality of Experience for the user of extended reality tools: I.e. the interaction with such tools must function to a high standard of quality for the human being. The use of such tools must be accepted by the human being and be individually compatible for him.
- Simulation and modelling, digital twins
    - Worker cognitive models, worker physiological response.
    - Digital Twins for Human Machine Interaction: I.e. simulation and modelling of the Human Machine Interaction in the digital twin factory environment; as part of the overall digital twin production process simulation. That enables more opportunities for experimentation than in a real factory environment.
    - Digital twins combined with process modelling including cognitive visualisation.
    - Integration of multi-sensor data for fine-grained digital twins, reconstructing the working environment more accurately
    - Development of digital twins that can be interpreted, used and operated by domain experts instead of only by data scientists or ICT experts
    - AI that is created in a simulated digital factory environment, and after virtual testing and experimentation rolled out into assistance systems used by humans in the physical, real production environment.
    - AR and VR has traditionally been focusing on experiencing and interacting with real and virtual 3D scenes, however their potential to exploit the capability of digital twins has yet to be unlocked. One field of future activities

shall be the integration of interactive simulation technology for digital twins into AR and VR user experiences.
    - Extended reality tools (e.g. VAR glasses) should effectively assist people and not cause stress or even make ill. Otherwise they will not be accepted and diffuse in production environments. Therefore, also alternative/new solutions to obstructive peripherals should be developed.
    - The ergonomic study of the human-machine interaction is essential to assure the worker well-being, safety, performance. The virtual reality and digital twin in factory environment is available today even though not intensively applied in design of production line or during the worker operations under healthy regulations.
    - The acoustic digital twin is now available improving the passive approach with static barriers or devices. The sensors in the workspace can inform in real-time when acoustic limits are overcome for the worker of the visitors.
- New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability
    - E.g certification of sensors for real time human state monitoring
- Skills and new training & learning concepts
    - Training and human skill augmentation (e.g. modular training/qualification, work based learning/training, Problem based learning and distributed MOOC (Massive Open Online Courses technologies);
    - A modular approach to training and skills development is critical in ensuring that the workers/students are capable of making their own qualification path aligned with their career path. But this is also relevant to facilitate the so needed upskilling and reskilling of the workforce
    - Eventually pilots for modular training, work base learning, problem based learning and "learning on the job" approaches in companies / SMEs to assess new tools & concepts of customized workforce qualification?
    - Ensure alignment between standards and delivered training and qualifications
    - Ensure transfer of knowledge and know-how from large companies to SMEs
- Standards, by ensuring that the human-device interaction is according to standards or supported by standards will ensure that companies can easily implement specific manufacturing technologies and devices

Additional observations, boundary conditions

- How will worker resilience and safety be enabled through early warning and smart interaction with surrounding technologies, locally or remotely? How can workers be connected and communicate with other workers in a situation of social distancing to avoid social isolation?
- Important: Careful selection of application scenarios.
- Creation of an European Framework for qualifications in manufacturing, supported by an European wide Quality assurance system and specific tools, is needed to ensure mobility and collaboration between the different EU regions in Europe

2.4.3 R&I Objective 4.3: Human & technology complementarity and excellence in manufacturing

General objectives and scope

Made in Europe will address human-technology complementarity in achieving excellence in manufacturing.

This means, the **need for increased overall productivity and flexibility** of the European manufacturing industry **are combined with the need for human-centred and human-driven manufacturing processes**. In this respect, technical aspects of human-machine interaction as well as organisational aspects of changing manufacturing and value creation processes must be tackled.

Generation of safe and productive collaborative environments for operators and increasingly automated machines and processes are the baseline of accomplishing excellent manufacturing complementarity between humans and technology. User friendly and interactive environments in manufacturing, human technologically enhanced capacities (sensorial through AR, or physical through exo-skeletons, among others) in combination with human ingenuity and flexibility are critical for increased productivity in highly competitive sectors.

The interaction of machines / robots with humans is an important aspect, in particular the detection of humans and the interpretation of human behaviour and assistance needs by machines as part of a safe interaction (e.g. control of machines by humans via gestures). This requires the development of artificial intelligence (AI) for assistance systems that enables the context-sensitive, flexible and individual recognition of needs on the human side.

Key Technologies and enablers

- Smart mechatronic systems, devices and components
    - Human activity sensing (stress, activity, vital signs, etc), In situ worker monitoring (emotional and physiological state)
    - Human muscle augmentation (e.g. exo-skeleton technologies and human-robotic symbiosis);
    - Robot learning by demonstration/observation: by demonstration through humans and observing them as well as by listening, the robot learns, imitates and then can do the task itself (especially in relation to manual activities). Self-learning Robots could learn from other “robot apprentices” via networked IoT / AI / Big Data, subsequently become a skilled worker itself, and train other robots or even people.
    - Faster and more flexible physical assistance systems: Physical assistance systems in collaboration with humans (cobots) are becoming increasingly important (e.g. cobot as a “third hand” for workers). Overall goal: Man and machine (cobot) divide tasks in the best and most efficient and effective way, i.e. also exchange tasks with each other (e.g. deburring, welding, gluing,

handling, packaging, loading). As if skilled workers were working together with other skilled workers or with an apprentice.
  - Sensor systems with different modalities: Camera, laser, time of flight, ultrasound, radar, IMU, etc. are major components for rule-based (physical) but also machine learning-based process control and object handling tasks (e.g. gripping, positioning). Apart from sensor data analysis, methodologies for fusing multimodal sensor data are important research and development tasks in order to be able to handle different materials, processes and environmental conditions. Future machine learning will play an important role in factories of the future, particularly for the detection, classification and determination of the position / pose of objects for handling and various process control tasks.
  - Task sharing Human-Machine, Capability-based task sharing, Cycle time-based task sharing
- New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability
  - Human capabilities could be augmented to a great extent by several generic and enabling technologies, but the technology perspective should not dominate. The level of automation and allocation of functions and tasks between people and manufacturing technologies leverage both humans and technologies (=> organizational aspects of “dynamic ad-hoc work planning” e.g. in a “hybrid” work system with worker and cobot(s) as “third hand” assistance)
  - Safety and protection for humans at the workplace, including infection prevention
  - Safety concerns are a barrier to the use e.g. collaborative robots etc
- Standards and standardization
  - Solutions (Standards) for affordable safety and security certification, in particular for mobile and/or flexible systems with changing applications

Additional observations, boundary conditions and initiatives

- User acceptance and regulation (safety, privacy, …) requires the participation of the workers right from the beginning
- An European approach for preparing the necessary workforce is needed but also collaboration and mobility between the different EU regions to ensure that the available workforce is place/located where it is needed
- Human-centered and human-driven manufacturing innovation cannot just be around the creation of tools to facilitate the integration of humans in a manufacturing environment. The need for identifying and deploying the right set of skills should be one of the priorities. All future topics, even if related to other Specific Objectives, should target the training of the workforce to ensure the implementation of the developed results.
- The present and future effects of the ongoing pandemic will likely lead to new requirements in terms of worker resilience and protection, remote work and human supervisory control of advanced manufacturing, isolation/separation of workplaces

to protect from infection, etc. This has many technological as well as organisational implications. Manufacturing resilience should not be seen as being opposed to lean and new strategies, involving humans and human-driven manufacturing innovation should be considered.

- Partnership Industry-Education system: reinforce the development of new working force (more attractive models for apprenticeship, across national borders) but also consider new stimulating and rewarding all-life-long training models for the existing working force.

2.4.4 R&I Objective 4.4: Manufacturing Innovation and change management

General objectives and scope

The implementation of innovative solutions is often subject to reluctance, either associated with potential failure or because decision-makers and/or the workforce are faced with the unknown. **Change management approaches** are required to provide clear insights into the risks and benefits that are associated with change while involving all stakeholders in the process. This should also be associated with anticipating the required skills. Intelligent technologies will need to adapt to their users, while also addressing privacy and understanding workers. It is also important to empower and engage workers to co-design future tools and work practices, and to consider personal preferences in the process of manufacturing innovation and change management. *Made in Europe* will define such change management approaches.

Key Technologies and enablers

- New business and new organisational approaches, including links with regulatory aspects such as safety, data ownership, and liability
    - Safety, privacy, liability, accountability
- Standards and standardisation
    - Innovation management system (e.g.ISO 56002:2019)
- Skills and training, from the operator to the manager covering blue and white collar.
    - Development of training and qualifications, at all levels, that support the implementation of innovation in large companies but also in SMEs
    - Modular approach to qualification/training of the workforce in order to facilitate and accelerate the adoption of innovation by companies

Additional observations, boundary conditions and initiatives

- Training and innovation activity tools can be integrated within the working environment. The focus should be on blended approaches, combining in class room training with online training or on the job training with virtual training
- Also consider responsiveness in crisis and change management.
- There is a "mental" side - mindset of people - that need to be addressed, but there is a technical side as well to secure that new solutions actually work and are reliable, to gain trust and to facilitate the speed of transformation.

2.4.5 R&I Objective 4.5: Technology validation and migration paths towards full industrial deployment of advanced manufacturing technologies by SMEs

General objectives and scope

Made in Europe will provide and support migration approaches from as-is situation towards innovative solutions. Support is required for testing, validation and industrialisation of advanced technologies in particular for SMEs, herewith enhancing the exploitation of project results. The I4MS projects for testing and validation, known from the Factories of the Future PPP under Horizon 2020 are providing a good model of such activities, lowering the risks associated to manufacturing innovation. Huge reskilling effort is needed and should be integrated in projects dedicated to SMEs.

The goal is also to integrate in or with the projects a set of exploitation-oriented activities including project partners and external stakeholders/potential users. Activities should include training, such as virtual training, distance learning, multipurpose training, learning or teaching Factories

Collaboration with new/external partners allows to know/learn more about the needs of users and the (extended) potential of the technology, methods, manufacturing processes. It increases the probability of project success and uptake. It also increases the commitment of partners and the visibility of the project for potential customers.

3 Planned Implementation

3.1 Activities

Activities are foreseen at five different levels:

3.1.1 Made in Europe projects

Stakeholder engagement and input-collection for call topics:

The association EFFRA has organised a series of workshops, conferences and consultations to identify opportunities for European industry and identify research challenges that need to be tackled. The collected expert knowledge is summarised and formulated in this present document on the future scope of the Made in Europe Partnership. In the annex of this document, the structure of the Strategic Research and Innovation Agenda is described. This structure is the result of a public consultation which took place in autumn 2018 and beginning of 2019.

During spring/summer 2020, EFFRA carried out a second consultation. More information and possible updates about this consultation can be found here.

The consultation requested responses from two perspectives:

(i) the perspective of experts and their respective organisations (companies, research institutes, universities etc) and
(ii) the perspective of projects, herewith drawing the relation to recent and ongoing developments.

Similar to consultations carried out by EFFRA in the past, these consultations are open. Anyone can contribute. The input that is provided by the respondents remains available and editable by those that contributed. It is therefore possible that based on the received input, stakeholders are asked to elaborate their feedback in order to improve its usability for the development of the SRIA.

Experts were asked to

- indicate the Objectives and the Research & Innovation Objectives that they would like to see addressed during the first three years of the partnership .
- for those Objectives and the Research & Innovation Objectives that were indicated as relevant, experts are asked to explain in a few sentences:
  - which technologies and approaches they would see as essential for the research and innovation activities
  - which other boundary conditions or activities would be essential in order to achieve impact
  - what would be the Key Performance Indicators in order to measure the impact and what would be the target values for these KPIs.

In addition, Project coordinators were asked to describe

- what the project has contributed essentially
- which future developments are in particular necessary, drawing from the 'lessons learnt' in the project

Beyond companies, research institutes, universities etc, the consultation also reached out to members state representatives and National Contact Points, as well as sectoral organisations and the associations linked to other Partnerships that are in preparation.

The received input will be used for the compilation of the detailed Made in Europe Strategic Research and Innovation Agenda (SRIA). The input will provide insight in the prioritisation of the research & innovation objectives, the focus in terms of specific challenges and enablers, as well as impact (and associated KPIs).

TRL levels addressed

Based on the feedback from the wider manufacturing community, regarding TRL levels addressed, there is a wish that the majority of calls shall cover TRL 5-6, with exceptional calls on TRL 3-5 and TRL 6-7.

Regarding the size of projects, the Made in Europe partnership shall cover both, big and small projects, to reflect the different needs and characteristics of the manufacturing industry needs: while SMEs prefer smaller projects, in other specific cases bigger projects are needed for having higher impacts on a specific technology or challenge. Also, the "cascading of funds" will be used where deemed necessary, to reach out to even more SMEs.

Dissemination and promotion of published calls; special focus on newcomers (especially from EU-13 countries) and SMEs

All actors involved in the Made in Europe Partnership will engage in promoting collaborative research opportunities. Special attention will be given to countries and regions, which were in the past underrepresented in European research. Moreover, manufacturing SMEs will be a special focus group that will be systematically approached in order to get involved in calls. EFFRA will be actively disseminating Made in Europe partnership and associated calls in events that have high participation of EU-13 countries. The open portal will highlight success stories from SME participation and help newcomers to enter into project proposals. Digital Innovation Hubs and similar regional ecosystems shall be contacted in order to stimulate participation of newcomers and small companies.

3.1.2 New approach for the dissemination of project results

The European manufacturing community has over the past years gained experiences in helping projects to disseminate results and help in any aspects linked to commercialisation. The Made in Europe Partnership will build on these past efforts and boost them further.
Marketing structures will be set up in order to help with the matchmaking: to bring exploitable results to those companies which were searching a desired solution/technology.

3.1.3 Beyond project work: increasing impact by creating insight across the programme, creating synergies among the projects and stimulating cross-Partnership cooperation

One of the roles of EFFRA is to ensure that projects do not stay "within silos" but that they engage with related work beyond the specific project. Many activities will be carried out on top of the work done by the individual projects, stimulating the sharing of information with many companies and organisations within and outside the Partnership.

The annual Made in Europe Community Days and thematic events.

Made in Europe project results will be made visible and widely disseminated during the annual 'Made in Europe Community Days'. This yearly event will build on the successful annual events organised by EFFRA, where project representatives meet and share the outcome of their projects, not only with other key actors in projects from the Made in Europe Partnership (such as industrial companies that host demonstrators or pilots), but also beyond the partnership. [6]

In addition, EFFRA will organise thematically focused events, for instance focussing on circular economy, artificial intelligence, etc… all this according to the requirements and the key priorities of the programme. These events will be organised in cooperation with other Partnerships when appropriate.

Information sharing and community building via the EFFRA Innovation Portal

The main goal of the EFFRA Innovation Portal is to provide an online resource for sharing information about any research and innovation work (including associated results and demonstrators) in the area of manufacturing. The EFFRA Innovation Portal includes all Factories of the Future Partnership projects and also includes projects from other programmes and initiatives on manufacturing.

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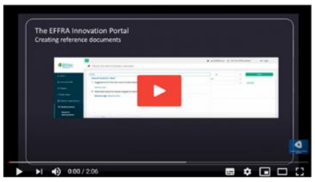
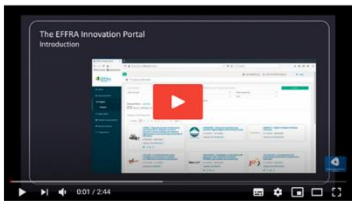
[6] The concept of "Community Days" has proven to be very successful in the past, as demonstrated in the Factories of the Future PPP . Projects are invited to demonstrate their results, which is interesting for companies, business angels and investors. During thematic parallel sessions, links to other partnerships are established, as for example done during the in 2019, with dedicated workshops organised with the Big Data community, the 5G community and so on.

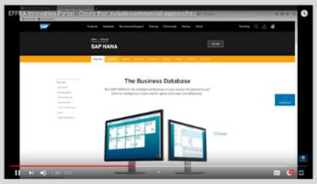
EFFRA Innovation Portal - Creating reference documents



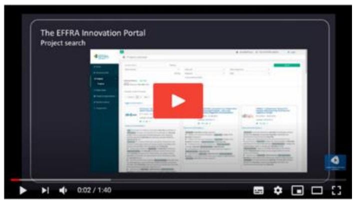
EFFRA Innovation Portal - Editing projects and results



EFFRA Innovation Portal – Cases that include commercial approaches



EFFRA Innovation Portal - Project Search



EFFRA Innovation Portal - Imports from the EU Open Data Portal

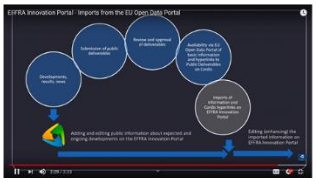


Figure 10: Video tutorials about the collection and sharing of information via the EFFRA Innovation Portal

Developing a structured insight into the overall transformation of manufacturing industry across the Factories of the Future/Made in Europe programme and other manufacturing research & innovation programmes:

The development of Pathways to digitalisation of Manufacturing is an activity that was developed by the Connected Factories Coordination action. The approach of positioning research and innovation results and demonstrators/pilots on different pathways is progressively extended across the existing FoF programme. This will become one of the approaches to establish strategic intelligence across the planned Made in Europe Programme and cooperate with other Partnerships.

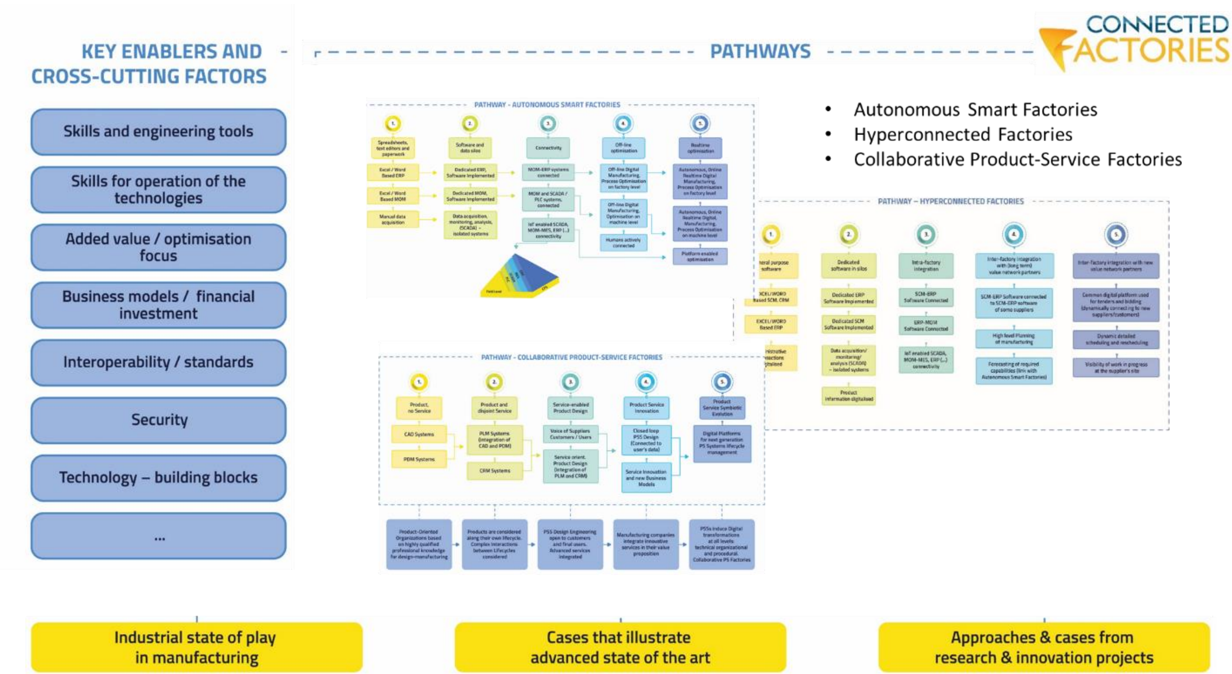


Figure 11: Pathways to digitalisation of Manufacturing

The structured approach to monitoring cross-cutting factors & enablers and the collection of cases & demonstrators across many programmes and initiatives, including Digital Innovation Hubs, is a key activity, in particular addressing the need for synergies across the Horizon Europe Programme.

Standardisation

EFFRA collects information about standardisation from the projects on a continuous basis (see also the section on Standards in the deliverable on cross-cutting aspects from the ConnectedFactories CSA https://www.connectedfactories.eu/cross-cutting-factors) and works towards more cooperation in this field[7]. EFFRA will enhance the depth of this information collection and dissemination throughout the Made in Europe Partnership. The section on standards and standardisation of the structured wiki on the EFFRA Innovation Portal that also serves as a mapping framework of project's activities and results, is being extended and fine-tuned in the course of 2020, taking into account work of the Industry 4.0 Standardisation Council and associated work on standards categorisation on international level.

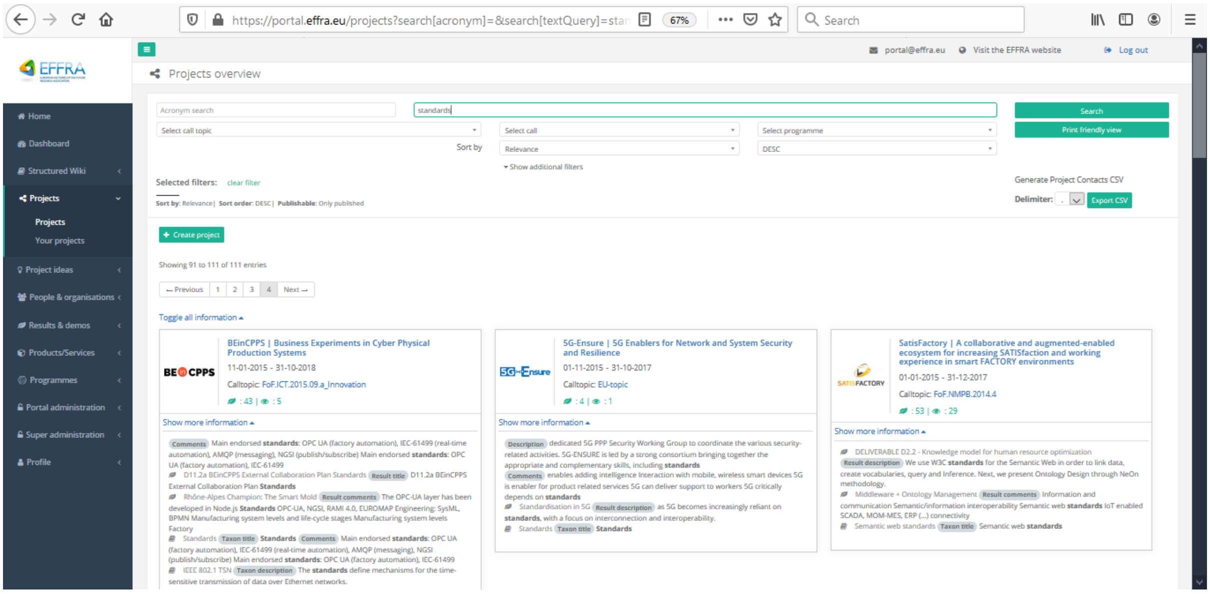


Figure 12: Screenshot is taken from this standards search on the project page

Skills and human aspects

Similar to standardization and many other key enablers or factors, strategic intelligence will be built in the domain of skills and humans in manufacturing. Information will be collected, structured and disseminated (both, through meetings and the Portal). The collected information will support the work of the associated working groups and advisory board (see governance).

[7] EFFRA acted for example as advisory board member in the Bridgit2 project which developed this website https://www.standardsplusinnovation.eu/

The following search on 'human' in the results and demonstrator section illustrates the results of past work.

3.1.4 Reinforced cooperation with national manufacturing initiatives

Besides the execution of Made in Europe call topics within the framework of Horizon Europe, the cooperation with manufacturing initiatives of individual member states initiatives is crucial.

In many member states, national partnerships between public and private are taking place. At the level of ManuFuture and EFFRA, these national initiatives have informally cooperating with each other for many years.

Within the framework of the Made in Europe Partnership, this cooperation will be further reinforced and formalised. As EU member states differ in specialisation of industries, the Memoranda of Understanding will need cover different elements of cooperation.

Beyond this bilateral cooperation between the Made in Europe Partnership and individual national initiatives, a **Made in Europe Council of National Initiatives** will be established. The Council of National Initiatives will have an advisory role to support EFFRA and the Made in Europe partnership aligning its actions. In addition, the Council members will spread out information of Made in Europe all over Europe.

All these activities will not only lead to a higher impact of both Made in Europe and the national initiatives, but it will also avoid a repetition of efforts.

3.1.5 Combining regional funding and resources

Another important means to increase the impact of the Made in Europe Partnership consists in better anchoring its activities on a regional and local level. Existing cooperation will be reinforced. EFFRA and its members are already interlinked with the Smart Specialisation policy (notably the Smart Specialisation Platform for Industrial Modernisation) and with RIM plus activities. More means will be invested in this cooperation, especially in linking up to research infrastructures and pilot facilities that support the research & innovation activities of the Made in Europe Partnership. Demonstrating and deploying Made in Europe research results on a regional and local level will ensure further take-up and commercialisation. Moreover, it will lead to more regional and structural funds being invested in manufacturing related activities.

The Vanguard initiative, with its currently 30 manufacturing-intensive NUTS-2 EU regions, provide a perfect means to disseminating projects results stemming from Made in Europe work and bring them one step further to commercialisation. A strategic partnership between Made in Europe and the Vanguard initiative will be developed.

3.1.6 Cooperation with other European or international initiatives

The Made in Europe Partnership - as the lighthouse for applied manufacturing research, technology development and innovation in Europe - will exchange and align strategic concepts with the ETP ManuFuture and the EIT Manufacturing, which complement the Partnership in technological foresight and in manufacturing-related education and business creation. For example, the ambitious goals of EIT KIC Manufacturing to enhance entrepreneurship and new business based on manufacturing innovations, can be nourished with research results from Made in Europe calls.

Beyond these manufacturing initiatives, further cooperation between the Made in Europe Partnership and other initiatives are envisaged and will be ensured. The Made in Europe Partnership will engage intensively with both, technology-focused initiatives and application-oriented initiatives.

At international level, the **World Manufacturing Forum** and **CIRP** will allow dialogues and collaboration with non-European players.

The following graph provides an overview of initiatives which relate to the Made in Europe Partnership and with which collaboration in one form or the other will be developed:

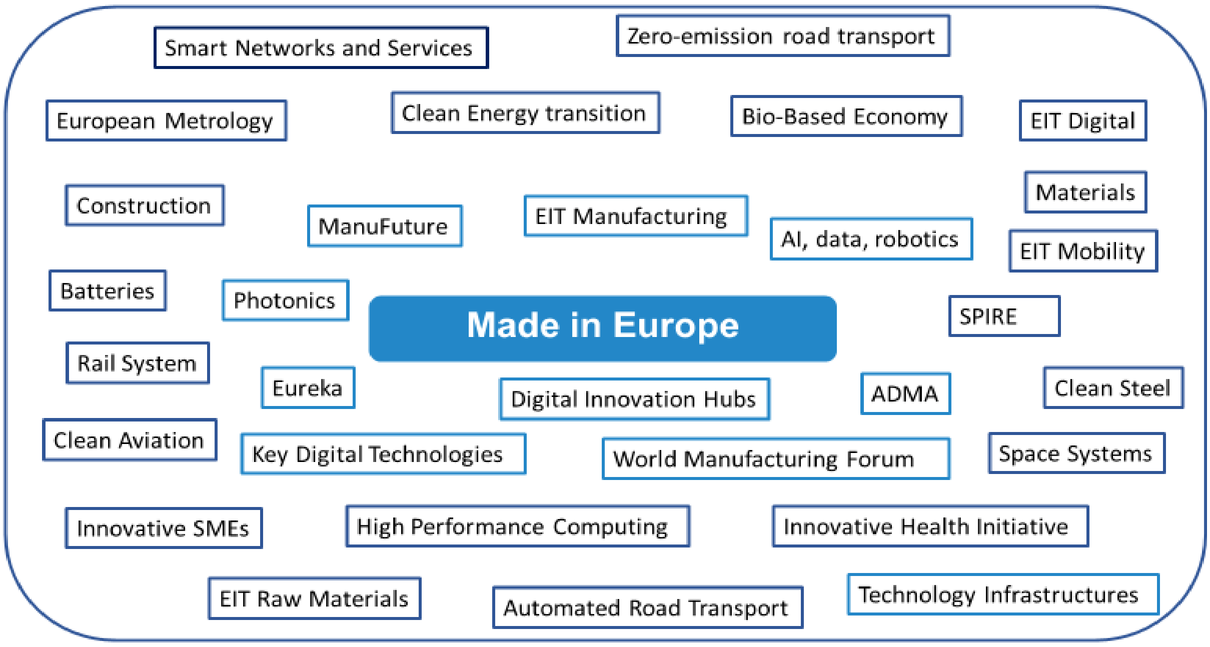


Figure 13: Overview of initiatives which relate to the Made in Europe Partnership and with which collaboration will be developed:

One should distinguish here between different activities, which all require another form of engagement:

a. Cooperation with the EIT Manufacturing initiative:

The Made in Europe Partnership and the EIT Manufacturing are two distinct initiatives with different goals and rules. EFFRA is in close contact with the EIT Manufacturing in order to ensure complementarity and cooperation, in particular regarding the further deployment of the technologies and approaches that are developed and demonstrated by Made in Europe and the mobilisation of education and training networks in support of this deployment.

EFFRA and the EIT Manufacturing will be jointly identifying Made in Europe research results which can take advantage of EIT Manufacturing programmes and tools. In particular, joint efforts will be made to foster the manufacturing workforce with the right skills for the future and support further investments in research outcomes.

b. Cooperation with other complementary manufacturing initiatives & activities and European level:

- Digital Innovation Hubs that are active in manufacturing. Made in Europe will develop innovative solutions that are rolled out to a large amount of manufacturing companies, especially SME, through Digital Innovation Hubs. At the same time, DIHs can provide input of SME needs to Made in Europe.
- Eureka (including the Eureka SMART and the ITEA3 Cluster programme)
- The INTERREG Europe programme
- ADMA, aiming at the harmonisation of the assessment and transformation processes while supporting manufacturing companies in becoming a 'Factory of the Future'
- Relevant ERA-Nets
- any IPCEI that might emerge if it has a link to manufacturing

Coordination work planned:
A continuous dialogue with these initiatives to compare roadmaps, indicate inspiring examples that provide a common state-of-the-art awareness and pointers to existing experience that can be multiplied across sectors, search for complementarity and engage in further cooperation opportunities.

c. Cooperation with technology-focused or input related (material/energy) activities:

Cooperation will be developed with following partnerships/areas/organisations:

- **AI/Big Data/robotics:** The proposed Partnership on AI, Data & Robotics will develop technologies that are crucial for manufacturing industries. Made in Europe will enhance the use of these technologies in the manufacturing sector. Cooperation between the two partnerships will focus on AI-enabled, adaptable, resilient factories and supply networks; advanced robotics solutions and human-robot collaboration in factories; data-driven business models and data-sharing solutions for manufacturing industries. Collaboration with the AI, robotics and manufacturing DIHs will also be enhanced.

- **Photonics:** Lasers are prominent enablers in advanced manufacturing, including additive manufacturing, surface treatments and texturing, joining technologies and also measuring technologies for high-precision manufacturing. The Made in Europe will integrate these photonics-based enablers into many applications, serving a variety of manufacturing sectors.
- **Embedded Systems/Smart Components:** Made in Europe will facilitate collaboration with the planned Key Digital Technologies partnership about common issues such as the industrial need for reliable and cybersecure solutions and trusted low-power components; AI, machine learning and machine vision systems for production; Circular production of intelligent systems; Connectivity and interoperability across industrial systems etc.
- **Security:** Made in Europe will build on the existing cooperation with ECSO and the experience generated by the recently started 'Security for manufacturing projects' that have already brought together the manufacturing and cybersecurity community.
- **5G:** as already showcased at EFFRA workshops on 5G and manufacturing, 5G will be a major enabler for exploiting the massive amount of data that is collected by embedded systems and sensing devices. Vast amounts of feed digital twins and allow for real-time monitoring and optimisation.
- **Materials:** Advanced materials are major enablers of high-performance and sustainability in many manufacturing sectors, reducing energy consumption and enabling circular economy. This brings about important challenges in terms of the competitive manufacturing of these products.
- **ISO standardisation (OPC-UA, Data eco-systems):** Interoperability in digitalised manufacturing, quality uniformity of materials for additive manufacturing are examples of challenges that to a large extent depend on standardisation.

Coordination work planned:
The forms of collaboration will take many forms such as common meetings and conferences, dissemination of results, scoping of joint topics of interest, policy papers, white papers, contributions to standards etc. Continuous dialogue on priorities and results, work done or work in the pipeline, establish feedback loops and provide information on manufacturing requirements, for e.g. materials/AI/5G/security etc. Manufacturing is both user and integrator of these technologies/inputs.

d. Cooperation with application sector application-oriented initiatives and other horizonal initiatives:

Sectors specific initiatives:

- **Transport (automotive, aerospace, space, trains, waterborne etc):** The synergy between product development processes and production engineering and manufacturing is one of the challenges that is addressed by Made in Europe. The interaction with such "application sector" initiatives will focus on the anticipation of requirements and the awareness of available technologies that can have an impact on different sectors at the earliest stages

- **Process Industry:** Process industries will work more tightly with the value chains to ensure that the materials developed by the process industries will be suitable for the circular economy. The Process industry partnership and Made in Europe will collaborate to strive towards circularity, integration and data sharing along the supply chain and facilitation of innovative reuse, re-manufacturing and recycling solutions.
- **Health:** tracking and tracing of production, rapid response and reconfiguration and rapid upscaling of manufacturing capabilities (as illustrated by the Covid-19 situation) are key characteristic of future manufacturing.
- **Energy and renewable energy:** MIE will generate the manufacturing systems that can produce the energy-systems of the future. From another perspective, energy technologies that reduce energy consumption in manufacturing.

Coordination work planned:
Continuous dialogue on priorities and piloting activities will be facilitated. Exchanging inspiring examples will be brought forward to stimulate uptake and wide deployment of results. Made in Europe will provide high-performance manufacturing solutions needed by these application sectors.

Other horizontal initiatives:

- ERC projects
- ERASMUS Plus
- The EIC
- RecoverEU

These programmes touch upon manufacturing, although they have other priorities. Continuous dialogue on similar activities and identification of cooperation will be developed.

Others:

- **Battery value chain:** Collaboration with MIE is particularly important to reduce dependency on imported raw materials and intermediate products for battery production and to improve the environmental footprint of battery production. Advanced manufacturing technologies are to be developed for reliable, cheap large scale production.
- **Living and working in a health-promoting environment:** MIE has a big interest in working together with the Horizon Europe Health Cluster on health and safety related topics at the work place.

Coordination work planned:
Continuous dialogue on priorities and identification for cooperation.

3.2 Resources

The Made in Europe Partnership is embedded in a network of thousands of industrial companies in Europe, which annually invest dozens of billion Euros into research and innovation.[8]

The funding that will be invested in overcoming the challenges and opportunities identified by the Made in Europe Partnership, will concentrate on collaborative research between companies, institutes and universities. The activities financed by partners, directly or indirectly associated with the Made in Europe Partnership and its research and innovation framework, will be following:

- Costs incurred by companies associated to the financing of demonstrators or pilot lines;
- In-kind contributions to the funded projects (on the basis of non-reimbursed eligible costs), with lower funding rates for higher TRLs;
- Private company research funding directly or indirectly linked to the Made in Europe R&D&I framework;
- Additional investments being done by companies where the trigger of the investments will come from technology advances provided by Made in Europe Partnership projects;
- Private funding which companies invest in national and regional initiatives that relate to the Made in Europe Partnership-

3.3 Governance

Made in Europe calls will be open and competitive. There will be no artificial barrier or fee to participate in the programme.

The governance consists of a continuous interaction between three groups of actors: (i) the wider manufacturing stakeholder community, (ii) the European Commission and (iii) the member states:

[8] https://iri.jrc.ec.europa.eu/scoreboard/2019-eu-industrial-rd-investment-scoreboard#field_report

Figure 14: Governance: interaction among three groups of actors

Each actor involved has a specific role:

i. EFFRA is unifying the broader manufacturing community and is expressing the interests of the manufacturing industry needs (EFFRA will take into account any expert knowledge, irrelevant of whether this organisation is a direct EFFRA member or not); moreover, EFFRA accompanies projects once they are launched.

ii. The European Commission, which organises the Made in Europe call topics process, the selection for evaluators and execution of the projects.

iii. Member states will be included in the broader governance of the partnership by adequate mechanisms.

It is extremely important that as many actors as possible are heard and can express themselves. EFFRA will bring together manufacturing expertise from various sectors, for example:

- machinery and other technology providers (machine tools, robotics and other suppliers of production equipment)
- industrial ICT solution and software providers
- automotive, aerospace and consumer goods industry i.e. the users of production equipment
- component suppliers
- material providers (steel, chemicals, power manufacturers for additive etc)
- Research and Technology Organisations (RTOs)
- Universities active in applied research or education related to manufacturing
- industry associations and clusters, which provide access to 100.000s of SMEs which are part of the EFFRA network.

The **interactions between the European Commission and EFFRA** will be organised through the **Made in Europe Partnership Board**. Manufacturing experts from EFFRA and European Commission officials will meet regularly to jointly decide how the Strategic Research Agenda will be transformed into actual Made in Europe calls topics.

Moreover, EFFRA will organise four distinct **work streams**, which will feed EFFRA an the Made in Europe Partnership Board with input and will accompany the projects. The four work streams will relate to the four objectives of Made in Europe:

- A work stream on Excellent, Responsive and Smart Factories and Supply Chains
- A work stream on Circular Products & Climate-neutral manufacturing
- A work stream on New Integrated Business, Product-Service and Production Approaches; new use models
- A Working stream on Human-centred and human-driven manufacturing innovation

As explained above, connections to national and regional manufacturing innovation experts and decision makers will be enhanced by the new Council of National Initiatives.

3.4 Openness and transparency

The Made in Europe Partnership needs to be designed in a way to allow **full openness and transparency**. This is not only important in terms of fairness, but also in terms of quality: the whole process needs to attract the best experts in the field and allow “outside of the box” thinking.

Openness and transparency will be ensured at all stages of the process, within the framework that legal requirements allow. This concerns both the competition stage as well as the execution of the projects. Project results will be available on an open portal and will be widely disseminated.

Summary overview and Intervention Logic: